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PTO/SB/05 (08-00)

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PATENT APPLICATION
TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 11309-001

First Inventor Gilbert Verghese

Title IMAGE TRACKING SYSTEM AND METHOD

Express Mail Label No.

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☒ Fee Transmittal Form (e.g., PTO/SB/17)
(Submit an original and a duplicate for fee processing)
2. ☒ Applicant claims small entity status.
See 37 CFR 1.27.
3. ☒ Specification [Total Pages 49]
(preferred arrangement set forth below)
- Descriptive title of the invention
 - Cross Reference to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to sequence listing, a table, or a computer program listing appendix
 - Background of the Invention
 - Brief Summary of the Invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
4. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 17]
5. Oath or Declaration [Total Pages 2]
- a. ☒ Newly executed (original or copy)
- b. ☐ Copy from a prior application (37 CFR 1.63 (d))
(for continuation/divisional with Box 17 completed)
- i. ☐ **DELETION OF INVENTOR(S)**
Signed statement attached deleting inventor(s)
named in the prior application, see 37 CFR
1.63(d)(2) and 1.33(b).
6. ☐ Application Data Sheet. See 37 CFR 1.76

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7. ☐ CD-ROM or CD-R in duplicate, large table or
Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission
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- a. ☐ Computer Readable Form (CRF)
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- i. ☐ CD-ROM or CD-R (2 copies); or
 - ii. ☐ paper
- c. ☐ Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. ☐ Assignment Papers (cover sheet & document(s))
10. ☐ 37 CFR 3.73(b) Statement ☐ Power of Attorney
(when there is an assignee)
11. ☐ English Translation Document (if applicable)
12. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
13. ☐ Preliminary Amendment
14. ☒ Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
15. ☐ Certified Copy of Priority Document(s)
(if foreign priority is claimed)
16. ☐ Other:

17. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP)

of prior application No.:

Prior application information

Examiner

Group I Art Unit.

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

18. CORRESPONDENCE ADDRESS

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FEE TRANSMITTAL for FY 2001

Patent fees are subject to annual revision.

Complete if Known

Application Number	N/A
Filing Date	N/A
First Named Inventor	Gilbert Verghese
Examiner Name	N/A
Group Art Unit	N/A
Attorney Docket No.	11309-001

TOTAL AMOUNT OF PAYMENT (\$) 1,101.00

METHOD OF PAYMENT

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:
- Deposit Account Number 022095
- Deposit Account Name Bereskin & Parr
- ☒ Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17
- ☒ Applicant claims small entity status. See 37 CFR 1.27
2. ☒ Payment Enclosed 3366
- ☒ Check ☐ Credit card ☐ Money Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE						
Large Entity		Small Entity		Fee Description	Fee Paid	
Fee Code	Fee (\$)	Fee Code	Fee (\$)			
101	710	201	355	Utility filing fee	355.00	
106	320	206	160	Design filing fee		
107	490	207	245	Plant filing fee		
108	710	208	355	Reissue filing fee		
114	150	214	75	Provisional filing fee		
SUBTOTAL (1)				(\$)	355.00	

2. EXTRA CLAIM FEES					
Total Claims	Extra Claims	Fee from below	Fee Paid		
79	-20** = 59	9.00	531.00		
Independent Claims	5	-3** = 2	40.00	80.00	
Multiple Dependent			135.00	135.00	

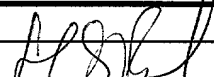
Large Entity		Small Entity		Fee Description
Fee Code	Fee (\$)	Fee Code	Fee (\$)	
103	18	203	9	Claims in excess of 20
102	80	202	40	Independent claims in excess of 3
104	270	204	135	Multiple dependent claim, if not paid
109	80	209	40	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent
SUBTOTAL (2)				(\$) 746.00

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES					
Large Entity Fee Code (\$)	Small Entity Fee Code (\$)			Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for <i>ex parte</i> reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	390	216	195	Extension for reply within second month	
117	890	217	445	Extension for reply within third month	
118	1,390	218	695	Extension for reply within fourth month	
128	1,890	228	945	Extension for reply within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,240	241	620	Petition to revive - unintentional	
142	1,240	242	620	Utility issue fee (or reissue)	
143	440	243	220	Design issue fee	
144	600	244	300	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	710	246	355	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	710	249	355	For each additional invention to be examined (37 CFR § 1.129(b))	
179	710	279	355	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	
Other fee (specify) _____					
* Reduced by Basic Filing Fee Paid					
SUBTOTAL (3)					(\$)
					0.00

SUBMITTED BY

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Signature		Date	October 31, 2000		

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BP #11309-001

BERESKIN & PARR

UNITED STATES

Title: IMAGE TRACKING SYSTEM AND METHOD

Inventor: Gilbert Verghese

09/02/99 11:01:00

Title: IMAGE TRACKING SYSTEM AND METHOD

FIELD OF THE INVENTION

The present invention relates to an image tracking system, and more particularly to an image tracking system for video conferencing or
5 computer based image communication applications.

BACKGROUND OF THE INVENTION

Increases in computer processor speeds into the Ghz region, and increases in bandwidth capacities and transmission speeds of networking devices are providing personal computer users with the
10 capabilities of watching live camera generated images as they are transmitted across the internet.

These advances have increased the quality of transmitted images and feasibility of video conferencing using personal computers in both the home and the office. The importance of video conferencing for
15 quick and efficient communication in the business world places a need for effective video conference systems for the personal computer which use low cost commercial components to achieve dynamic features suited to a live conference environment.

There are many instances during a video conferencing
20 session whereby the user is required to move from behind his or her computer in order to demonstrate or present a device, object or corporate information of some sort. To achieve such a dynamic video conferencing environment, an image tracking system which includes an image capture device such as digital camera must effectively track a user's movements.
25 Such a system must be easily installed on the computer and comprise a light weight, low cost and easily manufacturable mechanical components for providing efficient camera movement.

United States Patent No. 4,264,928 describes a video conference system which uses a servo-motor controlled mirror to project the
30 image of a person at a conference room table onto a TV camera when he or

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she talks into a microphone. The invention provides a method of tracking a person when they speak into a microphone. Based on the strength of the signals received from each persons microphone, the servo-motors position the mirror to project the image of the person talking onto the TV camera.

5 This system is limited to televising conferences where all participants are in the same room rather than providing video conferencing for participants in remote geographical locations. Furthermore, the system incorporates motors for rotating a mirror rather than rotating the inherent weight of the TV camera.

10 United States Patent No. 5,416,513 describes a video camera for tracking an object by comparing a specific color picked from the image to a specific color stored as a reference. Based on the processed results from comparing the specific color stored as a reference and the image received from the camera, a motor rotates and tilts the camera to follow the region in
15 which the specific color signal detected in the image is larger than in others. However, a mechanical structure for providing efficient tilt and pan movements has not been defined.

United States Patent No. 5,606,368 describes a pan and tilt mounting system for providing movement for cameras and related devices.
20 The use of a cable drive in the system eliminates the inaccuracy inherent in similar gear driven systems. The invention does not pay particular attention to the mounting position of the motors which affects the movement efficiency. The invention discusses a tilt motor for controlling tilt movement and a pan motor for controlling rotational (panning) movement, whereby the
25 mass of the tilt motor is subject to the rotational movement provided by the pan motor. This type of "motor loading" configuration reduces the efficiency of the pan motor and increases the torque requirements.

Accordingly, there is a need for an image tracking system for video conferencing or computer based image communication applications
30 which is capable of effectively and efficiently tracking the movements of a user, which is relatively inexpensive to manufacture and which is easily operable.

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SUMMARY OF THE INVENTION

It is therefore an object of the present invention in one aspect to provide image tracking system for use with an image capture device which obtains digitized image frames of an object, the image tracking system comprising:

- 5 (a) a support for holding the image capture device;
- (b) a processing device for determining an object location value for the object based on the digitized image frames generated by the image capture device;
- 10 (c) a position control device coupled to the support for, in use, rotating the support and the image capture device mounted therein about two axes based on the object location such that the object remains within a center region of each of the digitized image frames, said position control device comprising:
 - 15 (i) a base;
 - (ii) a first motor mounted on the base for generating a first rotational movement based on the object location and a first rotatable member mounted to the base for rotation about a first axis, said first rotatable member being connected to the first motor; and
 - 20 (iii) a second motor mounted on the base for generating a second rotational movement based on the object location and a second rotatable member comprising the support mounted to the first rotatable member for rotation about a second axis and being connected to the second motor.
- 25

In another aspect, the present invention provides an image tracking system for use with first and second image capture devices which obtains digitized image frames of an object, the image tracking system comprising:

- 30 (a) a first support for holding the first image capture device and a second support for holding the second image capture device;
- (b) a processing device for determining an object location value for

the object based on the digitized image frames generated by the image capture device;

(c) a position control device coupled to the support for, in use, rotating the first and second supports and the first and second image capture devices mounted therein about four axes based on the object location such that the object remains within a center region of each of the digitized image frames, said position control device comprising:

(i) a base;

(ii) a first motor mounted on the base for generating a first rotational movement based on the object location and a first rotatable member mounted to the base for rotation about a first axis, said first rotatable member being connected to the first motor;

(iii) a second motor mounted on the base for generating a second rotational movement based on the object location and a second rotatable member mounted to the first rotatable member for rotation about a second axis and being connected to the second motor;

(iv) a third rotatable member comprising the first support and a fourth rotatable member comprising the second support, said third and fourth rotatable members being mounted on the second rotatable member, at least one of said third and fourth rotatable members being rotably mounted to said second rotatable member; and

(v) a third motor mounted on the base for providing relative rotation between said third and said fourth rotatable members.

In another aspect, the present invention provides a method of tracking an object, said method comprising the steps:

(a) obtaining a series of digitized image frames from the image capture device;

- (b) identifying the object within each of the digitized frames; and
- (c) providing a first rotational movement to the image capture device about a first axis using a first motor and providing a second rotational movement to the image capture device about a second axis using a second motor such that the object remains within a center region of each of the digitized frames.

In another aspect, the present invention provides a tension regulation device for controlling the amount of tension applied to a tendon, said tension regulation device comprising:

- (a) a platform;
- (b) a resilient column rotatably mounted on the platform and having a cross-section with a first radius;
- (c) a splined column rotatably mounted on the platform and having a plurality of spline members extending radially and having a cross-section with a second outer radius, said splined column being adapted to receive a portion of the tendon therearound;
- (d) said resilient column being spaced apart from said splined column and rotatably mounted on said platform at a distance equal to slightly less than the sum of the first and second radius; and
- (e) such that in the absence of tension the spline members slightly deform said resilient column to restrict rotational movement of said spline column and said tendon and in the presence of tension, the spline members are forced to travel along the surface of said resilient column and to unwind the portion of the tendon around the splined column.

In another aspect, the present invention provides a tendon motor pulley for coupling a tendon length to a motor shaft, said tendon motor pulley comprising:

- (a) a first disc;
- (b) an second disc, the first and second discs having facing surfaces;

- (c) a hub positioned concentrically between said first and second discs; and
- (d) at least one engagement means extending between the first and second discs and located radially outwardly from the hub, whereby a tendon can travel freely around the hub and the engagement means engages the tendon.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a block diagram of a preferred embodiment of the image tracking system of the present invention;

Fig. 2 is a perspective view of a position manipulating device of the image tracking system of Fig. 1;

Fig. 3A is a vertical cross sectional view of the position manipulating device illustrated in Fig. 2 along the line AA';

Fig. 3B is a horizontal cross sectional view of the position manipulating device illustrated in Fig. 3A along the line BB';

Figs. 4A and 4B are cross-sectional views of the collar member of the image tracking system of Fig. 1;

Fig. 5A is a top view of the neck member of the image tracking system of Fig. 1;

Fig. 5B is a side view of the neck member of the image tracking system of Fig. 1;

Fig. 6A is a top view of the camera support member of the image tracking system of Fig. 1

Fig. 6B is a side view of the camera support member of the image tracking system of Fig. 1

Fig. 7 is a cross sectional view of the neck member of the image tracking system of Fig. 1;

Figs. 8A and 8B are top views of the tension release mechanism installed in the neck member of the image tracking system of Fig. 1;

Figs. 9A and 9B are bottom views the tension release mechanism

installed within the collar member of the image tracking system of Fig. 1;

Figs. 10A and 10B are perspective views of the assembled tendon motor pulley of the image tracking system of Fig. 1;

5 Figs. 10C and 10D are perspective views of the upper and lower tendon wheels, respectively, of the image tracking system of Fig. 1;

Figs. 11A and 11B are cross-sectional views of the assembled tendon motor pulley, shown engaged by a tendon;

Fig. 12 is functional flow diagram illustrating the functionality of the image tracking program of the image tracking system of Fig. 1;

10 Fig. 13A is a front view of an alternative embodiment of the position manipulation device of image tracking system of Fig. 1;

Fig. 13B is a side view of the position manipulation device of Fig. 13A;

Fig. 13c is a top view of the position manipulation device of Fig. 13A; and

15 Fig. 14 is a screen capture of the CONTROL SCREEN™ user interface generated by the user interface software of the image tracking system of Fig. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference is first made to Fig. 1, which show a functional block diagram of the image tracking system 10 made in accordance with a preferred embodiment of the invention. The image tracking system 10 comprises a hardware subsystem 12 and software subsystem 35. The hardware subsystem 12 includes a digital video camera 16, a motor driver 24, a first motor device 18 and a second motor device 22. The software subsystem 35 includes a user interface 38 and an image capture and processing stage 40. The image capture and processing stage 40 comprises a camera driver component 42, an image processing component 44 and a motor control interface component 46.

OVERVIEW

30 Generally, the image tracking system 10 processes digitized images

that are received from an image capture device such as camera **16**. Image processing of the digitized images generates a location value corresponding to the object image. Based on this location value, appropriate control signals are generated for controlling the orientation and position of the video camera. The orientation and position of the camera is varied in order for the camera to track the movement of an object image within the digitized image, wherein the object image is a human subject. While the following discussion will assume that camera **16** is a digital video camera, it should be understood that any type of image processing device could be used (e.g. analog video camera) in conjunction with an appropriate data conversion device for generating digital data for use by image tracking system **10**.

Still referring to Fig. 1, the user interface **38** provides features such as a software generated graphical window for viewing the camera generated image, also allowing the user to control the size and quality of the image within the window. Other features of the user interface **38** include the ability to override the image tracking function of the image tracking system **10** in favour of user positioning, whereby the user can directly position and move the camera **16** by appropriately operating a computer pointing device.

The camera driver **42** provides the necessary synchronization and data accessing protocol, for interfacing image data corresponding to digitized image frames generated by the video camera **16** to the image processing component **44**. The camera driver **42** ensures that image data is presented to the image processing component **44** at the required rate (any rate) and that the image processing component **44** can access image data corresponding to any region (an object image) within each of the digitized image frames. The camera driver **42** essentially provides the necessary interfacing between different cameras and manufacturer-supplied drivers, and the image processing component **44**.

Once the image data is received by the image processing component **44** of the software subsystem **35**, a color tracking algorithm is used for determining an area of color associated with a human subject within the

digitized image. The color associated with a human subject could be pre-set to be a certain labelling color (i.e. a blue colored wearable button) or it can be the person's skintone. The color region of a human subject is located within the digitized image by scanning image pixels. For efficient
5 real time color detection, the pixel area occupied by the digitized image is scanned radially, where the radial scanning starts at the center of the image, moving progressively outwards toward the border of the image. While the following discussion will assume that the color region to be analyzed for a particular human subject is in fact their skintone, it should be
10 understood that any other type of color region could be used for subject tracking and identification.

Skintone detection is based on color values determined from the RGB-24 video signals from the video camera **16**. The pixels depicting skintone are detected and processed in order to generate a position of
15 optimal correlation, which corresponds to a center point within a prominent skintone region. This calculated center point is called a centroid and has coordinate position value, which is used to detect image movement and generate camera movement signals for tracking the skintone area of the human subject as he or she moves.

20 The motor control interface **46** within the software subsystem **40** communicates with a position control device referred to as a motor driver **24** using a communication link **48**, such as a direct link, an RS232 serial link, USB or wireless link. The motor driver **24** comprises a microcontroller device (see Fig. 3A, reference character **114**) with programmed firmware for
25 receiving and processing position movement instructions from the motor control interface **46**.

The motor control interface **46** transmits a two byte position movement instruction frame to the motor driver **24**. The instruction frame comprises:
30 two control bits for indicating a selected servo-motor for positional manipulation, an 8-bit word for generating the value of positional movement or manipulation required by the selected servo-motor, and control bits for indicating the status of the servo-motors (e.g. standby mode). The 8-bit word

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representing positional movement, corresponds to 256 discrete position values, wherein each position value generates a specific angular displacement for either the first motor **18** or the second motor **22**. In accordance with the present invention the first and second motor **18**, **22** are servo-motors responsible for the rotation movement and tilt movement of the camera **16** respectively. However, it will be appreciated that other types of motor device, data communication protocol, and position resolution values may be used in association with the image tracking system **10**, without departing from the scope of the present invention.

The motor driver **24** controls the positional movement of the first motor **18** and the second motor **22** by converting the corresponding values of positional movement (0-255) received from the motor control interface **46** (command frames) to a first and second pulse width modulated (PWM) control signal. The first and second PWM control signals are responsible for generating rotational movement for the first and second motors **18**, **22**. The PWM signal is a pulse train having a fixed period (e.g. 20 ms) with a variable pulse width (e.g. 1-2 ms). Each value of positional movement (0-255) received by the motor driver generates a PWM signal of specific pulse width value.

Once the PWM signal from the motor driver **24** is received by the designated motor (first motor **18** or second motor **22**), based on the pulse width of the PWM signal, the designated motor's shaft rotates to a specific angular position somewhere in the range of 0-180 degrees. The motor **18**, **22** positions are normally initialized to a mid-range position of 90 degrees by applying a 1.5ms PWM signal to their input. By varying the PWM signal between 1.5ms and 1ms, the first and second motor **18**, **22** shafts will rotate between 90 and 0 degrees. Similarly, by varying the PWM signal between 1.5ms and 2ms, the designated motor's **18**, **22** shaft will rotate between 90 and 180 degrees.

30 **IMAGE TRACKING HARDWARE**

Fig. 2 shows a three-dimensional perspective view of a position

manipulating device **70** for both mounting and varying the positional movement of the camera (not shown). The position manipulating device **70** comprises a collar member **80** which provides the first rotational movement. The second rotatable member of the position manipulating device **70** is a neck member **72** which provides the second rotational movement.

Position manipulating device **70** also includes a direction indicator **71** mounted on the front surface of position manipulating device **70** which is adapted to indicate operation to the user. Specifically, direction indicator **71** comprises an UP indicator **71a**, a DOWN indicator **71b**, a LEFT indicator **71c**, a RIGHT indicator **71d** and a TRACKING indicator **71e**. UP indicator **71a**, a DOWN indicator **71b**, a LEFT indicator **71c**, and RIGHT indicator **71d** all indicate the direction in which position manipulating device **70** is moving. TRACKING indicator **71e** indicates to the user that image tracking system **10** has identified the subject and is tracking the subject.

The neck **72** has a hemispherical shape which supports and secures an annular shaped camera support member **75**. The video camera (not shown) is mounted on the position manipulation device **70** by means of the camera support member **75** attached to the neck **72**. The position manipulating device **70** further includes a stationary base member **90** for contacting a support surface **68** and supporting the collar member **80**, the neck **72** and the camera support member **75**. The first rotational movement of the collar **80** is a pan movement (rotation) and the second rotational movement of the neck **72** is a tilt movement.

Therefore, the video camera (not shown in Fig. 2) is rotated by means of the pan movement of the collar **80**, whilst being simultaneously tilted by the tilt movement of the neck **72**. The first motor **18** generates the first rotational movement referred to as the pan movement of the collar member **80**, and the second motor **22** generates the second rotational movement referred to as the tilt movement of the neck **72**.

Fig. 3A shows a vertical cross sectional view along the line AA' of the position manipulating device **70** illustrated in Fig. 2. The base member **90** is hollow and houses a mounting member **100**, the motor driver which

comprises a microcontroller device **114**, and both the first and second motors **18, 22**. The mounting member **100** rigidly attaches to a set of four securing points **92** (only two are shown) on the base member **90** by means of four securing screws **93** (only two are shown). The mounting member

5 **100** includes a first vertical shaft portion **108** for engaging the collar member **80**. The collar member **80** comprises a cylindrical cavity region enclosed within a cylindrical housing **82**, wherein the cavity region receives the first vertical shaft portion **108** of the mounting member **100** such that the collar member **80** is rotatably mounted on the first vertical shaft portion **108**.

10 Consequently, the base member **90** and attached mounting member **100** are stationary with respect to the rotatable collar member **80**. The pan movement of the collar member **80** has a first plane of rotation **127** about a fixed first rotation axis, as defined by **125**. The pan movement of the collar member **80** defines the pan movement of the position manipulating device

15 **70**.

Fig. 3B shows a horizontal cross sectional view along the line BB' of the position manipulating device **70** illustrated in Fig. 2. Specifically, the mounting member **100** is shown having four securing points **92** and the securing screws **104** which couple the motors **18, 22** to the under surface

20 **102** of the mounting member **100**. Further, first vertical shaft portion **108** is shown in cross-section located at the center of mounting member **100**. Also shown is a motion restricting member **69** which is adapted to restrict pan motion of the collar **80** to within a range of approximately 160° as indicated by angle A. It should be understood that other movement ranges could be

25 implemented within position manipulating device **70** by suitably changing the configuration of motion restricting member **69**. The first tendon member **95** is shown passing through a first opening **103** and extending around first vertical shaft portion **108**.

As will be discussed in more detail in Figs. 9A and 9B, a tension

30 release mechanism **255** comprises a second rotatable splined column **268** and a second rotatable second column **262** which are mounted on a platform **290** and rotatably coupled to first vertical shaft **108**. The lateral

separation between the second splined column **268** and the second rotatable second column **262** is less than the sum of their radii. The tension release mechanism **255** protects the first tendon member **95** from breaking due to the collar **80** being physically forced to rotate when the first rotatable
5 motor shaft **96** of the first motor **18** is either stationary, or rotating in the direction opposing that of the induced force, as will be further discussed in respect of Figs. 9A and 9B.

The microcontroller **114** is mounted on an electrical circuit board **110** and receives position movement instruction frames from the motor control
10 interface **46** via an electrical connection **118** connected to an electrical connector **117** mounted on the electrical circuit board **110**. It will be appreciated that the position movement instruction frames from the motor control interface **46** may be transmitted to the electrical circuit board by any suitable communications means, such as a direct link, an RS232 serial
15 link, USB or wireless link. The microcontroller **114** processes the received movement instruction frames for the purpose of controlling the movement direction and magnitude of the collar **80** and neck **72** by means of motors **18** and **22** respectively.

The neck **72**, further comprises a pair of cylindrically shaped securing
20 members **142** (only one shown in Fig. 3A) for rotatably connecting the neck **72** to a pair of retaining slots **131** (only one shown) located at the upper securing portion **81** of the collar member **80**. The neck **72** rotatably tilts relative to a pivot point, wherein the pivot point is defined by the engagement of the pair of cylindrically shaped securing members **142** on the neck **72**
25 with each pair of retaining slots **131**.

As the neck **72** tilts about the pivot point, it has a second plane of rotation **122** about a second rotation axis, as defined by **120**. The pan movement of the collar **80** relative to the tilt movement of the neck **72** is such that the second rotation axis, as defined by **120**, of the neck **72**, rotates
30 about the first fixed rotation axis, as defined by **125**, of the collar **80**. In the current embodiment of the present invention, the first fixed plane of rotation, as defined by **127**, of the collar **80** and the second plane of rotation, as

defined by **122**, of the neck **72** are perpendicular. The tilt movement of the neck **72** defines the tilt movement of the position manipulating mechanical structure **70**.

The first motor **18** comprises a first rotatable motor shaft member **96** and the second motor **22** comprises a second rotatable motor shaft member **98**. Both motors **18**, **22** are stationary with respect to the neck **72** and collar **80** and are connected to the under surface **102** of the mounting member **100** by means of a second set of four securing screws **104** (only two are shown). The first motor shaft member **96** of the first motor **18** has a third rotation axis (not shown) which is longitudinally concentric with the first motor shaft member **96**. Similarly, the second motor shaft member **98** of the second motor **22** has a fourth rotation axis (not shown) which is longitudinally concentric with the second motor shaft member **98**. Both motors **18**, **22** have been secured to the mounting member **100**, wherein the mounting member **100** is stationary relative to the rotatable neck and collar member **72**, **80**.

The third rotation axis of the first motor shaft **96** and the fourth rotation axis of the second shaft **98** are stationary and fixed relative to each other. Therefore, each motor **18**, **22** independently provides pan and tilt movement for the collar **80** and neck **72** without for example the first motor **18** carrying the mass or load of the second motor **22**. Consequently, the mounting position of the motors (**18** and **22**) is such that neither the first motor **18** providing pan movement nor the second motor **22** providing tilt movement carries the mass or load of the other motor (**18** or **22**).

A first tendon member **95** couples the rotational movement of the first motor shaft member **96** to the collar member **80** which in turn causes the collar **80** to rotate about the first vertical shaft portion **108**. The first tendon member **95** comprises a first segment and a second segment, where each segment has a first end and a second end. At the first end, the first segment of the first tendon **95** is attached to the circumference of the first motor shaft member **96**. Similarly, at the first end, the second segment of the first tendon **95** also attaches to the circumference of the first motor shaft

member **96**.

Consequently, at the first end, the first and second segments of the first tendon member **95** form a loop around the first motor shaft **96**. As the tension on the first end of the first tendon **95** increases due to the first motor shaft **96** rotating, the attachment of the first and second segments to the first shaft member **96** avoids any slipping of the first tendon **95** relative the first motor shaft **96**. It will be appreciated that in accordance with the present invention, the first tendon member **95** is defined as a segment of string, cord, rope, wire or other filament that under pulling tension at one end can cause movement at the other.

The collar member **80** further comprises a second vertical shaft portion **84** located near the base of the collar **80**, wherein the second vertical shaft portion **84** receives the second end of the first tendon member **95** for coupling the first motor shaft **96** rotation to the collar **80**. The first vertical shaft **108** is concentric with the second vertical shaft **84**, wherein the second vertical shaft **84** rotates about the first vertical shaft **108**.

At the second end, the first segment of the first tendon **95** is attached to a fixed point (not shown) on the circumference of the second vertical shaft portion **108** of the collar member **80**. Also, at the second end, the second segment of the first tendon **95** is attached to a fixed point (not shown) on the circumference the second vertical shaft portion **108**. Consequently, at the second end, the first and second segments of the first tendon member **95** form a loop around the second vertical shaft portion **108**. As the tension on the second end of the first tendon **95** increases due to the first motor shaft **96** rotating, the attachment of the first and second segments to the second vertical shaft portion **108** avoids any slipping of the first tendon **95** relative the second vertical shaft portion **108**. The first tendon member **95** passes through a first opening **103** in the mounting member **100** when connected between the first motor shaft member **96** and the second vertical shaft portion **108** of the collar **80**. By connecting the first tendon **95** between the first motor shaft member **96** of the first motor **18** and the second vertical shaft portion **108** of the collar member **80**, the rotation of the first motor shaft

member **96** is coupled through the first tendon **95** to the second vertical shaft portion **84** causing the pan movement of the collar **80**.

Clockwise rotational movement of the first motor shaft **96**, as defined by directional arrow **B**, is transferred through the first tendon **95** to the collar member **80**, causing the first tendon **95** to rotate or pan the collar **80** in a clockwise motion, as defined by directional arrow **B'**. Conversely, anti-clockwise movement of the first shaft **96** is transferred through the first tendon **95** to the collar member **80**, causing the first tendon **95** to rotate or pan the collar **80** in an anti-clockwise motion. The first fixed plane of rotation, as defined by **127**, of the collar **80** rotates about the first fixed rotation axis, as defined by **125**, wherein the first fixed rotation axis, as defined by **125**, is referred to as the major rotation axis. Hence, in accordance with the present invention, the major rotation axis which occurs due to the pan movement is fixed.

A second tendon member **99** couples the rotational movement of the second motor shaft member **98** to the neck **72**, which in turn causes the neck **72** to tilt about the pivot point **142** defined by the engagement of the neck **72** with each pair of retaining slots **131**.

The second tendon member **99** comprises a first end, a central portion, and a second end located at the opposite end to the first end. At the first end, the second tendon **99** is attached to the circumference of the second motor shaft member **98**. Similarly, the second end of the second tendon **99** also attaches to the circumference of the second motor shaft member **98**. The length of tendon between the two end points is extended from the second motor shaft **98** to the neck member, where the central portion of the tendon **99** is attached to the neck **72** by means of a first slit region **74** and a second slit region **76** located at opposing positions on the body of the neck **72**. A cavity region within the hemispherical shaped neck **72** provides a means for passing the central portion of the second tendon member **99** through the neck **72**. The central portion of the second tendon member **99** is passed through the hollow region of the neck **72** by passing between the first and second slit region **74**, **76** (for a clearer

illustration of one of the slit regions, refer to Fig. 7).

Consequently, the first end and second end of the second tendon member **99** form a loop around the second motor shaft **98** and the neck **72**. As the tension on the first and second end of the second tendon **99** increases due to the second motor shaft **98** rotating (clockwise and anti-clockwise), the attachment of the first and second ends to the second shaft member **98** avoids any slipping of the second tendon **99** relative the second motor shaft **98**. It will be appreciated that in accordance with the present invention, the second tendon member **99** is defined as a segment of string, cord, rope, wire or other filament that by applied tension at one end can cause movement at the other.

Referring to Fig. 7, the second tendon **99** is placed within each slit region **74** (only **74** shown) and pushed to the base location **148** of the slit **74**, where the second tendon rests against the body of the neck as it exits the neck towards the second shaft member **98**.

As illustrated in Fig. 3A, a hollow bore region within the first vertical shaft **108** provides a channel for passing the second tendon **99** between the second motor shaft **98** and the neck **72**. The second tendon member **99** passes through a hollow region of the neck **72** and exits the neck **72** at the first and second slit region **74**, **76** locations.

Both portions of the second tendon **99** exiting the slit regions **74**, **76** pass through a second opening **86** (also see Fig. 9A) at the top portion of the collar member **80** and a third annular opening **109** in the first vertical shaft **108** before connecting to the second motor shaft member **98** by means of the hollow bore of the first vertical shaft **108**. The rotation of the second motor shaft member **98** is coupled through the second tendon member **99** to the first or second slit region **74**, **76** causing the tilt movement of the neck **72** about the pair of pivotal points, defined by the engagement of the pair of cylindrically shaped securing members **142** (only one shown) on the neck **72** with each pair of retaining slots **131**.

Clockwise rotational movement of the second motor shaft **98**, as defined by directional arrow **C**, is coupled through the second tendon **99**

to the first slit region **74** on the neck **72**, causing an applied downward tension force on the first slit region **74**. This subsequently causes tilt movement of the neck **72** about the pair of pivotal points, defined by the engagement of the pair of cylindrically shaped securing members **142** on the neck **72** with each pair of retaining slots **131**. Directional arrow **C'** shows the direction of tilt movement for the neck as a result of the clockwise rotation of the second motor shaft **98**. Conversely, anti-clockwise movement of the second motor shaft **98** is coupled through the second tendon **99** to the second slit region **76** on the neck **72**, causing an applied downward tension force on the second slit region **76**. This causes tilt movement of the neck **72** about the pair of pivotal points in an opposing direction of rotation to that indicated by directional arrow **C'**.

The second plane of rotation, as defined by **122**, of the neck **72** rotates about the second rotation axis, as defined by **120**, wherein the second axis of rotation is referred to as a minor rotation axis. Hence, the minor rotation axis which occurs as a result of the tilt movement rotates about the fixed major rotation axis which occurs due to the pan movement.

In accordance with a preferred embodiment of the present invention, the position of the first and second tendons **95**, **99** are configured so that the respective pan and tilt movements do not apply additional unwanted tension on either tendon member (**95** or **99**). In other words, the movement of both the first tendon **95** and second tendon **99** are mutually independent of one another and neither rotatable member (neck **72** and collar member **80**) affects the other's movement. This is achieved by connecting the second tendon **99** in an approximately straight line path between the second motor shaft **98** and the neck **72**, whereby the second tendon is oriented so that a substantial portion of the second tendon is aligned with the stationary first rotation axis. As the first tendon member **95** provides pan movement, the minor axis of rotation corresponding to the tilt movement rotates about the second tendon member **99**. Therefore, no unwanted additional tension is applied to the second tendon **99** as a result of the pan movement about the major axis of rotation. By connecting a

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tendon which provides a minor axis of rotation, in a straight line between its motor shaft and movement actuating member (e.g. neck member or wheel mechanism), such that movement about a major axis of rotation (e.g. pan movement) causes the minor axis to rotate about the tendon corresponding with the minor axis, the movement about the major axis will not affect movement about the minor axis.

As shown in Fig. 3A, the camera support member **75** comprises a base surface **77** and a 1/4 inch camera mounting screw **79**, wherein the screw **79** engages a corresponding standard 1/4 inch thread that exists on most camera bodies. The base surface **77** supports the body of the camera, once the mounting screw **79** of the camera support member **75** is fully screwed into the thread (not shown) on the camera body.

Figs. 6A and 6B show two alternative views of the camera support member **75** from the side and above, respectively. The view from above shows the annular shape of the base surface **77**, which supports the body of the camera **16** once the camera **16** is attached to the camera support member **75**. The camera support member also includes a groove region **78** along its annular outer rim for snap fitting into the annular inner rim **126** (see Fig. 3) of the neck **72**.

Fig. 4 illustrates the pair of retaining slots **131** of the collar member **80** (only one shown) located at its upper securing portion **81**, wherein the pair of retaining slots **131** pivotally hold the neck **72** in place. Fig. 5 shows a perspective view from the top and side of the neck **72**. The side view shows the pair of cylindrically shaped contact members **142** for engaging the pair of retaining slots **131** of the collar **80** (illustrated in Fig. 4). Each of the retaining slots **131** comprises a channel opening between two vertical support walls **130**, wherein the walls **130** terminate above a circular recess **132**. The width of the channel between the walls **130** is slightly smaller than the diameter of each pair of the cylindrically shaped contact members **142** (as shown in Fig. 5B). The diameter of the circular recess **132** is approximately the same as the pair of contact members **142**.

As the pair of cylindrically shaped contact members **142** are

pushed into the pair of retaining slots **131**, the width of channel opening (one for each retaining member) increase to accommodate the contact members **124**. As the contact members **142** are pushed past the channel regions and into each recess area **132**, the width of each channel opening
5 returns to its original width. The diameter of the contact members **142** are larger than each channel opening width and therefore, the channel opening closes around the upper surfaces **126** of the contact members **142** (see Fig. 5) as they are pushed into each recess areas **132**. The diameter of the contact members **142** and each recess area **132** are such that the frictional
10 contact between the two (contact members and recess area) provides sufficient securing of the neck **72** to the collar **80** without restricting the pivotal or tilt movement of the neck **72**.

Fig. 8A is a top view of the neck **72**, whereby a tension release mechanism **230** is mounted within the hollow region of the neck **72**. The
15 purpose of a tension release mechanism is to avoid a tendon breaking as a result of forcibly rotating any rotatable members such as the neck or collar **72**, **80** in a direction opposing the corresponding motor's torque.

It will be appreciated that forcible rotation of a rotatable member in this way can overcome the tensile strength of a tendon. The
20 tension release mechanism **230** protects the second tendon member **99** from breaking due to the neck **72** being physically forced to tilt when the second motor shaft **98** of the second motor **22** is either stationary (i.e. not rotating), or rotating in the direction opposing that of the physically induced force. This is particularly useful, when users of the system may be of a
25 younger age group and more inclined to curiously try and force the neck **72** to tilt without the motor controlling the tension of the tendon member and consequently the neck **72** movement.

The tension release mechanism **230** comprises a rotatable splined column **232** having a first radius, and a rotatable second column
30 **245** having a second radius. The second radius of the second column **245** is defined as the distance from the center **248** of a circular cross section (e.g. top surface of column as shown in Fig. 8A) of the second column **245**

to the circumference of the circular cross section **249**.

The rotatable splined column **232** has a plurality of spline members **236** extending along its length, wherein each of the spline members **236** on the splined column **232** has an end portion **240**. The first
5 radius of the splined column **232** is defined as the distance from the center **234** of the splined wheel **232** to the tip portion **240** of each spline member **236**.

Both columns **232** and **245** are rotatably mounted on a platform (see Fig. 7 reference number **150**) such that the lateral separation
10 between the centers **234**, **249** of both columns is slightly less than the sum of both the first radius of the splined column **232** and the second radius of the second column **245**. Therefore, as the splined column **232** rotates, a spline member **236** will engage the second column **245** and restrict the rotation movement of the splined column **232**. The outer layer of the second
15 column **245** is made of an elastic type material such as rubber or plastic.

Consequently, if the spline column **232** is rotated with enough torque, the spline member **236** will compress and momentarily deform the outer layer (e.g. rubber or plastic) of the second column **245** causing the spline member **236** to rotate. Once the spline member **236** passes the
20 second column **245**, the portion of the outer layer which engaged the spline member **236** returns to its original shape. If the rotation torque applied to the splined column **232** is beyond a finite torque value, each of the spline members will forcibly rotate past the second column **245**. Therefore, the splined column **232** will rotate in discrete steps, wherein each discrete step
25 is defined by the distance between each of the spline members **236**. The columns **232**, **245** protect the second tendon **99** from excessive tension and the possibility of breaking, as described in the following paragraph.

Fig. 8B is a top view of the second tendon member **99** attached to the neck **72** and tension release mechanism **230**. As previously
30 described, the second tendon **99** passes through the first slit region **74** and the second slit region **76** located at opposing positions on the body of the neck **72**. However, instead of attaching the second tendon **99** to provide a

taut connection between the first slit region **74** and a second slit region **76**, a slack portion **247** of the second tendon **99** is provided, wherein the slack portion **247** is wrapped around the splined column **232** located between the slit regions **74**, **76**. A first portion **250** of the second tendon **99** extends from the splined column **232** through the first slit region **74** and connects to the second motor shaft **98**. A second portion **252** of the second tendon **99** extends from the splined column **232** through the second slot region **76** and connects to the second motor shaft **98**.

Under normal operation, the second motor shaft **98** of the second motor **22** rotates in a first direction and causes the neck **72** to pivot about the second rotation axis **120**. The second tendon **99** applies a downward tension on the first slit **74** and releases the tension from the second slit **76** causing the neck **72** to tilt. Similarly, the second motor shaft **98** of the second motor **22** rotates in a second direction causing the second tendon **99** to apply a downward tension on the second slit **76**, which releases the tension from the first slit **74** and causes the neck **72** to tilt in the opposite direction.

If a user physically forces the neck **72** to tilt without operating the motors **18**, **22**, the excess tension may cause the second tendon **99** to break. With the tension release mechanism **230** in place, the forced tilting action causes the first portion **250** of the second tendon member **99** to experience an increased tension along the direction of arrow **E**, whilst the second portion **252** of the second tendon member **99** experiences a released tension along the direction of arrow **G**. This in turn causes the slack portion **247** of the second tendon member **99** wrapped around the splined column **232**, to try and rotate the splined column **232** in a counter clockwise direction, as defined by arrow **E'**. If the tension on the first portion **250** of the second tendon **99** along the direction of arrow **E** is in excess of a finite limit, each of the spline members **236** of the splined column **232** will forcibly rotate past the second column **245**, causing the splined column **232** to rotate in the counter clockwise direction, as defined by arrow **E'**. As the splined column **232** rotates, the slack portion **247** of the second tendon **99**

is progressively unwrapped from the splined column **245** as forcible tilting of the neck **72** continues. This results in a reduced tension on the first portion **250** of the second tendon **99** along the direction of arrow **E**, thus avoiding breaking the second tendon **99**.

5 Similarly, if the forced tilting action causes the second portion **252** of the second tendon member **99** to experience an increased tension along the direction of arrow **G**, whilst the first portion **250** of the second tendon member **99** experiences a released tension along the direction of arrow **E**. This in turn causes the slack portion **247** of the second tendon member **99** wrapped around the splined column **232**, to try and rotate the splined column **232** in a clockwise direction, as defined by arrow **G'**. If the tension on the second portion **252** of the second tendon **99** along the direction of arrow **G** is in excess of a finite limit, each of the spline members **236** of the splined column **232** will forcibly rotate past the second column **245**, causing the splined column **232** to rotate in the counter clockwise direction, as defined by arrow **G'**. As the splined column **232** rotates, the slack portion **247** of the second tendon **99** is progressively unwrapped from the splined column **245** as forcible tilting of the neck **72** continues. This results in a reduced tension on the second portion **252** of the second tendon **99** along the direction of arrow **G**, thus avoiding breaking the second tendon **99**.

Referring back to Figs. 3A and 3B, it will also be appreciated that the body of the collar member **80** prevents forcible tilting of the neck **72** beyond absolute rotational limits.

25 Fig. 9A is a second tension release mechanism **255** identical in operating principle and mechanical structure to the tension release mechanism **230** shown in Fig. 8A and 8B and as previously shown in Fig. 3B. The tension release mechanism **255** protects the first tendon member **95** from breaking due to the collar **80** being physically forced to rotate when
30 the first rotatable motor shaft **96** of the first motor **18** is either stationary (i.e. not rotating), or rotating in the direction in the direction opposing that of the induced force. This is particularly useful when users of the system may be

of a younger age group and more inclined to curiously try and force the collar **80** to rotate without the motor controlling the tension of the tendon member and consequently the collar **80** movement.

The second tension release mechanism **255** comprises a second rotatable splined column **268** and a second rotatable second column **262**, where the lateral separation between the second splined column **268** and the second rotatable second column **262** is identical to that of columns **245** and **232** shown in Figs. 8A and 8B. The rotatable splined column **232** has a plurality of spline members **274** extending along its length.

As shown in Fig. 9A, the second rotatable splined column **268** is placed within a semi-circular recess **280** (also see Fig. 9B) near the base of the second vertical shaft **84** of collar **80**. Both columns **268** and **262** are rotatably mounted on a platform **290**, wherein the platform **290** connects to the second vertical shaft **84**. Therefore, as the second vertical shaft **84** of collar **80** rotates, so does the second tension release mechanism **255**. Fig. 9B is a cross-sectional top view of the second vertical shaft **84** and first tendon **95** without the second tension mechanism **255** in place. As previously described and illustrated in both Figs. 9B and 4, the first tendon **95** is both attached to a fixed point on the circumference of the second vertical shaft member **84** and wrapped around it. By including the tension release mechanism **255**, as shown in Fig. 9A, a second slack portion **286** of the first tendon **95** is provided, wherein the slack portion **286** is wrapped around the splined column **268** located in the semi-circular recess **280** of the second vertical shaft **84**. A first portion **282** of the first tendon **95** extends from the splined column **268** and passes around its circumference and connects to the first motor shaft **96**. A second portion **284** of the first tendon **95** also extends from the splined column **268** and passes around part of the circumference of the vertical shaft member before connecting to the first motor shaft **96**.

Under normal operation, the first motor shaft **96** rotates in a first direction and causes the collar **80** to rotate about the first vertical shaft

108 of the mounting member **100**. As the first motor shaft **96** rotates, the first tendon **95** applies an increased tension on the second vertical shaft **84** of collar **80** in the direction indicated by arrow **I**, whilst the tension on the second vertical shaft **84** in the direction of arrow **H** is reduced.

5 Consequently, the second vertical shaft **84** rotates the collar **80** in a clockwise rotational direction. Similarly, when the first motor shaft **96** of the first motor **18** rotates in a second direction, the first tendon **95** applies an increased tension on the second vertical shaft **84** of collar **80** in the direction indicated by arrow **H**, whilst the tension on the second vertical shaft **84** of
10 collar **80** in the direction of arrow **I** is reduced. Consequently, the second vertical shaft **84** rotates the collar **80** in an opposite anti-clockwise rotational direction.

If the user physically forces the collar **80** to rotate without operating the motors **18**, **22**, the excess tension may cause the first tendon
15 **95** to break. With the second tension release mechanism **255** in place, the forced rotation action causes the first portion **282** of the first tendon member **95** to experience an excess tension along the direction of arrow **H**, whilst the second portion **284** of the first tendon member **95** experiences a released tension along the direction of arrow **I**. This in turn causes the slack portion
20 **286** of the tendon member **95** wrapped around the splined column **268** to try and rotate the splined column **268** in a counter clockwise direction, as defined by arrow **H'**. If the tension on the first portion **282** of the first tendon **95** along the direction of arrow **H** is in excess of a finite limit, each of the spline members **274** of the splined column **268** will forcibly rotate past the
25 second rotatable second column **262**, causing the second splined column **268** to rotate in the counter clockwise direction, as defined by arrow **H'**. As the second splined column **268** rotates, the slack portion **286** of the first tendon **95** is progressively unwrapped from the splined column **268** as forcible rotation of the collar **80** continues. This results in a reduced tension
30 on the first portion **282** of the first tendon **95** along the direction of arrow **H**, thus avoiding breaking the first tendon **95**.

Similarly, if the forced rotation action causes the second

portion **284** of the first tendon member **95** to experience an excess tension along the direction of arrow **I**, the first portion **282** of the first tendon member **95** will experience a released tension along the direction of arrow **H**. This in turn causes the slack portion **286** of the tendon member **95** wrapped
5 around the splined column **268** to try and rotate the splined column **268** in a clockwise direction, as defined by arrow **I'**.

If the tension on the second portion **284** of the first tendon **95** along the direction of arrow **I** is in excess of a finite limit, each of the spline members **274** of the splined column **268** will forcibly rotate past the second
10 rotatable second column **262**, causing the second splined column **268** to rotate in the clockwise direction, as defined by arrow **I'**. As the second splined column **268** rotates, the slack portion **286** of the first tendon **95** is progressively unwrapped from the splined column **268** as forcible rotation of the collar **80** continues. This results in a reduced tension on the second
15 portion **284** of the first tendon **95**, along the direction of arrow **I**, thus avoiding breaking the first tendon **95**.

Figs. 10A and 10B are perspective views of a tendon motor pulley **299** which includes a lower tendon wheel **300** (Fig. 10C) and an upper tendon wheel **302** (Fig. 10D). Tendon motor pulley **299** is a relatively
20 simple assembly which can be used to secure two opposing tendons **310** and **312** (Figs. 11A and 11B) easily and securely.

Specifically, Fig. 10C shows a lower tendon wheel **300** which comprises a disk **301** from which extends two columns **304**, within which are formed two recesses **306** and a central recess **308**. Fig. 10D shows an
25 upper tendon wheel **302** which comprises a disk **321** from which extends two columns **320**, within which are formed two recesses **322** and an extending central hub **324**. As can be understood, columns **304**, **320** and recesses **306**, **322** of upper and lower tendon wheels **300** and **302** are formed so that when lower tendon wheel **300** is coupled to upper tendon
30 wheel **302**, the columns **304** are received in a precision fit within recesses **322** and columns **320** are received in a precision fit within recesses **306**. Further, the central recess **308** is formed so as to receive central hub **324** in

a precision fit.

Disk **301** of lower tendon wheel **300** has a knurled hole **330** which is adapted to receive a motor shaft (not shown). Disk **321** of upper tendon wheel **302** has a bore **332** which is adapted to receive a securing screw (not shown). A securing screw can be used to secure the tendon motor pulley **299** to a motor shaft (not shown). In this way, the tendon motor pulley **299** guides the tendon segment **310** or **312** around a substantially circular path concentric with the attached motor shaft. This ensures the tendon displacement is proportional to the angle of the motor shaft rotation.

Likewise, at the other end of the tendon **310** or **312**, a substantial circular tendon segment path centered around the actuating member's rotational axis further ensure the angle of motor shaft rotation is proportional to the actuated member's rotational angle.

Figs. 11A and 11B show how two opposing segments of a tendon **310** and **312** can be secured within tendon motor pulley **299**. In use, tendons **310** and **312** can be looped around central hub **324** and then upper and lower tendon wheels **300** and **302** can be coupled together so that the columns **304** are received in a precision fit within recesses **322** and columns **320** are received in a precision fit within recesses **306**. Most importantly, the central recess **308** is formed so as to receive central hub **324** in a precision fit. A securing screw is then used to secure upper and lower tension wheels **300** and **302** together and to the motor shaft (not shown). It should be noted that the tendons **310** and **312** are double-threaded for added strength.

25 **IMAGE TRACKING SOFTWARE**

The operation of the image tracking program (software and microcontroller firmware) is illustrated in the flow diagram of Fig. 12. The general principles of the image tracking program are related to concepts discussed in the research paper authored in part by the applicant entitled

"An active stereo vision system for recognition of faces and related hand gestures", R. Herpers, G. Verghese, L. Chang, K. Darcourt, K. Derpanis, R.F.

Enenkel, J. Kaufman, M. Jenkin, E. Milios, A. Jepson and J.K. Tsotsos, Proc. of 2nd Int. Conf. on Audio- and Video-based Biometric Person Authentication, University of Maryland, USA, March, 1999, pp. 211-216.

The process starts when the user activates image tracking
5 system 10 at step **499**. At step **500** and **502** the user selects the image tracking mode or the user positioning, as previously discussed. In user positioning, the user uses an appropriate pointing device (e.g. computer mouse or trackball) to position the digital video camera so that it displays a desired image on the computer screen or monitor. In contrast, in image
10 tracking mode, the image of a human subject is continuously tracked by the digital video camera using the skintone tracking algorithm. As the subject moves, the camera automatically tracks the subject's movement and displays the image on the screen or monitor.

Now referring to Figs. 12 and 14, in a step **504** the user may
15 select any desired camera position, wherein the user control screen **50** (see Fig. 14) allows the user to select a desired camera pointing position by selecting the left arrow button **52**, right arrow button **54**, up arrow button **58** and down arrow button **56**. Alternatively, the user may click any point in the displayed image frame to direct the camera to center that point. In a step
20 **506**, each time the arrow buttons (**52**, **54**, **56**, **58**) are clicked on (e.g. by a mouse) or an arrow key if pressed on the keyboard, a position movement instruction frame is generated for the purpose of providing camera movement in the direction of the arrow button clicked on. Continuous movement occurs while the button or key is pressed. In a step **520**, the
25 movement instruction frames corresponding to the activated (pressed or clicked on) arrow buttons (**52**, **54**, **56**, and **58** as shown in Fig. 14) are converted to specific pulse width modulated (PWM) signals which generate the movement of the motors **18**, **22**.

Each time a particular arrow button is activated a specific PWM
30 signal advances the position of the motors, based on the arrow button activated. If the left arrow button **52** or right arrow **54** button is clicked, the first motor **18** generates the pan movement for the position manipulating

device **70** and camera **16**. If the up or down arrow button **58**, **56** is clicked, the second motor **22** generates tilt movement for the position manipulating device **70** and camera **16**.

Two additional movement methods which can be implemented within the image tracking software of the present invention are the mouse-tracking and mouse-clicking modes. Specifically, in the mouse-tracking mode, all two dimensional mouse movements are translated to camera movements, until the user releases the mouse button. In the mouse-clicking mode, the software allows the user to click on a point in the image displayed on-screen and responds by moving to center in on that point.

In addition to the arrow buttons, mouse-tracking and mouse-clicking modes, movement of the position manipulating device and camera can be achieved through voice commands such as: "LOOK LEFT", "LOOK RIGHT", "LOOK UP", AND "LOOK DOWN".

In step **500**, if the image tracking mode is selected, the program moves to a step **508**, wherein the digital video image from the camera **16** is stored for subsequent image processing. The image data output from the digital video camera **16** is in 24-bit (RGB-24) color format transmitted at a rate of 30 Hz. In a step **510**, the retrieved stored digital image from the camera is radially scanned from the center of the digital image towards the outer border of the image in order to identify a region of skintone bordered by regions of non-skintone. The point on the digital image at which the radial scanning first starts can be from the center of the image, the previous centroid or defined by the user following a mouse click. In an alternative embodiment, it is possible to provide random access to camera image memory without entire image transmission and no frame rate limitation. In a further alternative embodiment, the tracking algorithm will run on a microcontroller within the device and not on the host computer.

In a step **512**, if a region of skintone is not detected, the program returns to step **510**, where the next digital image frame from the camera **16** is radially scanned for the purpose of identifying a region of

skintone. This process continues until a region of skintone is detected. If the radial scan detects a region of skintone bordered by non-skintone, in a step **514**, the centroid of the region of skintone is determined, wherein the centroid identifies the central position of the region of skintone. Once the

5 centroid of the digital image has been determined, in a step **516**, the coordinate position of the centroid is calculated. In a step **518**, the coordinate position of the centroid is compared with image center coordinates. The coordinate locations of both the centroid and the center of the image are processed in order to determine the displacement of the

10 centroid's coordinate location from the coordinate location of the center of the image. In the step **506**, the displacement of the centroid's coordinate location from the center of the image enables the generation of movement instruction, wherein the instruction frames specify camera **16** movement to effect displacement of the centroid to the center of the image.

15 In a step **520**, the movement instruction frames corresponding to the difference in the coordinate positions of the centroid and center of the image are converted to specific pulse width modulated (PWM) signals, where the PWM signals generate the movement of the motors **18, 22**. Depending on the position of the centroid relative to center of the image,

20 specific instruction frames are converted to PWM signal which move each motor **18, 22** independently based on whether the corresponding instruction frame determines horizontal pan movement or vertical tilt movement. For example, if the centroid is above and to the left of the center of the image, the first motor **18** will receive a PWM signal for initiating the pan movement

25 of the position manipulating device and camera, wherein the pan movement of the camera causes the centroid to move to the left and toward the center of the image. Similarly, the second motor **22** will receive a PWM signal for initiating the tilt movement of the position manipulating device and camera, wherein the tilt movement of the camera causes the centroid to move

30 downward toward the center of the image. During image tracking mode, the received digital images from the camera **16** are continually stored and radially scanned for the purpose of calculating the coordinate position of the

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5 Figs. 13A, 13B and 13C show perspective side, front and top views of an alternative embodiment of the position manipulating device **340** of the present invention, respectively. The second position manipulation device **340** provides a third rotational movement and a fourth rotational movement in addition to the first and second rotational movements which
10 refer to the already described pan and tilt movements.

The first motor **405** has a first rotatable shaft member **407**, wherein the first motor shaft is drivingly connected to the first rotatable member (not shown). The first rotatable member is a major rotation wheel which has a first rotational movement within a ball bearing filled annular rim member **342**. The first rotational movement is referred to as a major pan rotation movement (horizontal rotation), which is defined by a first plane of rotation **430** about a first rotation axis **432**. It will be appreciated that in accordance with the present invention the first motor shaft may incorporate a first tendon member (not shown) to actuate movement of the first rotatable member.

The second motor **377** has a second rotatable shaft member **477**, whereby the rotation of the second shaft **477** is coupled by a second tendon member **378** to the second rotatable member **343**. The second rotatable member is a tilt bar **343**. The tilt bar **343** undergoes a second rotational movement, wherein the second rotational movement is a tilt movement defined by a second plane of rotation **434** about a second

rotation axis **436**.

The third motor **381** has a third rotatable shaft member **390**, whereby the rotation of the third shaft **390** is coupled by a third tendon member **358** to the third rotatable member **346**. The third rotatable member **346** is a first minor rotation wheel **346**. The first minor wheel **346** undergoes a third rotational movement, where the third rotational movement is a first minor pan rotation (horizontal rotation), which is defined by a third plane of rotation **440** about a third rotation axis **442**.

Similarly, the fourth motor **379** has a fourth rotatable shaft member **479**, whereby the rotation of the fourth shaft **479** is coupled by a fourth tendon member **360** to the fourth rotatable member **348**. The fourth rotatable member is a second minor rotation wheel **348**. The second minor wheel **348** undergoes a fourth rotational movement, where the fourth rotational movement is a second minor pan movement (horizontal rotation), which is defined by a fourth plane of rotation **445** about a fourth rotation axis **447**. It will be appreciated that motors **405**, **381**, **377**, **378** are servo-motors identical to those described in the previous embodiment of Figs. 3A. It will also be appreciated that different types of motors may be used without departing from the scope of the present invention described and illustrated herein.

An image capture device comprising a first digital video camera **354** and a second digital video camera **356** are each enclosed in a first camera housing **350** and a second camera housing **352** respectively. The first camera housing **350** is attached to the first minor wheel **346** and the tilt bar **343** by means of securing member **366**. Similarly, the second camera housing **352** attaches to the second minor wheel **348** and tilt bar **343** by means of securing member **362**.

The tilt bar **343** attaches to a spring biasing member (not shown) and to the major wheel by means of securing members **383** and **364** respectively. As the tension on the second tendon **378** increases with the rotation action of the second shaft **477**, the tilt bar **343** tilts backward in the direction of arrow **A** against the tension in the spring member (not

shown). Conversely, as the tension on the second tendon **378** is reduced by rotating the second shaft **477** in the opposite direction, the tilt bar **343** tilts forward under the counter active force of the spring member (not shown).

Both the first minor wheel **346** and the second minor wheel **348** are also spring loaded using a first and second tension biasing spring (not shown). As the tension on the third tendon member **358** increases with the rotation action of the third shaft **390**, the first minor wheel **346** rotates against the tension force of the first tension spring. Also as the tension on the third tendon **358** is reduced by rotating the third shaft **390** in the opposite direction, the first minor wheel **346** rotates in the opposite direction under the counter active force of the first tension spring. Similarly, the tension on the fourth tendon member **360** increases with the rotation action of the fourth shaft **479**, where the second minor wheel **348** rotates against the tension force of the first tension spring. As the tension on the fourth tendon **360** is reduced by rotating the fourth shaft **479** in the opposite direction, the second minor wheel **348** rotates in the opposite direction under the counter active force of the second tension spring.

Consequently, both the first and second cameras **354**, **356** undergo first and second minor pan movement, tilt movement and major pan movement by individually actuating the first minor wheel **346**, second minor wheel **348**, tilt bar **343** and major rotation wheel (not shown). The configuration and positioning of the tendons **378**, **358**, **360**, motors **405**, **381**, **377**, **378** and rotatable members **346**, **348**, **343**, (major wheel member) is such that the axial rotation of each rotatable member is independent of all the other rotatable members. This means that rotating individual members about their axes does not restrict or affect axial rotations or orientations of other rotatable members.

This is achieved by ensuring that the second rotation axis **436** of the tilt member **343** (second rotatable member) rotates about the second tendon member **378** and the stationary first rotation axis **432** of the major wheel (first rotatable member). The second tendon **378** is oriented such that a substantial portion of the second tendon is aligned with the stationary first

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The position of the motors **405**, **381**, **377**, **378** within the position manipulation device **340** ensure that no motor is responsible for movement of the load or mass of any other motor. It will be appreciated that in accordance with the present invention, the first motor **405** can be
5 positioned below the major wheel and rim member **342**, where the first motor **405** can generate movement of the first major wheel by coupling the first motor shaft **407** movement through the use of a first tendon member. Fig. 13A shows that the first motor **405** directly mounted on the major wheel, where the first motor shaft member **407** rotates about a first shaft rotation
10 axis which is longitudinally concentric within the first motor shaft **407**. The second motor shaft member **477** rotates about a second shaft rotation axis which is longitudinally concentric within the second motor shaft **407**. Also, the third and fourth motor shaft members **390**, **479** rotate about a third shaft rotation axis and a fourth shaft rotation axis respectively.

15 The third and fourth shaft rotation axes are also longitudinally concentric within the third and fourth shaft members **390**, **479**. In accordance with the present invention, the first, second, third and fourth rotation axes of motors **405**, **381**, **377**, **378** are stationary and fixed relative to one another, each motor generates independent movement of the rotatable
20 members and each motor does not carry the load or mass of any of the other motors.

In the alternative embodiment shown in Figs. 13A and 13B the first and second digital video cameras provide stereo vision capability, wherein 3-dimensional digital image frames are generated. Each of the
25 first and second video cameras generates 2-dimensional image frames which are processed by means of image processing software in order to provide corresponding 3-dimensional image frames. Whilst stereo vision is already known in the art of robotics and image processing, the use of digital image frames with additional depth perception (third dimension of view)
30 provides more robust tracking capabilities with user enhanced three dimensional viewing using stereo glasses.

The instant invention also incorporates voice activated

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command options, which can be set up from the user control screen. This enables manual tracking of an object by the user by means of user defined voice commands. As previously discussed, the direction indicator **71** is mounted on the front surface of position manipulation device **70** and indicates to the user that the unit is in operation and further which direction (UP, DOWN, LEFT, RIGHT or a combination thereof) the camera is moving in.

Fig. 14 shows the user control screen **50** generated when the user interface software is first started. The user CONTROL SCREEN™ **50** includes a left arrow button **52**, a right arrow button **54**, an up arrow button **58**, a down arrow button **56**, Tuner button **62**, Tool Panel button **66** and a Track button **64**. The Track button **64** turns the image tracking feature ON and OFF. Once the image tracking feature is OFF, the left arrow button **52**, right arrow button **54**, up arrow button **58** and down arrow button **56** can be used to manually move the camera to display a the camera's video stream in the display portion **60** of the control screen **50**. With the image tracking switched ON, the camera will continuously track the image of the user in its field of view. The Tuner button **62** enables the user to fine tune the image settings, such as adjusting video levels for providing reliable tracking and optimizing the images shown on the display portion **60**. The Tool Panel button **66** enables the user to control the more advanced features of the image tracking system **10**, such as setting up video conferencing sessions, manipulating the display portion **60** size, voice command features and image control functions. Other features of the user interface software include capture of still camera images and adjusting the speed of image tracking.

It should be noted that image tracking system **10** provides a number of significant advantages to videoconferencing and computer users. Since the images are processed using an image processing algorithm, the servo-motors generate rotational movement for the position manipulating device and camera, such that the image of the user is constantly tracked. Also, the position manipulating device provides a configuration of

independent stationary servo-motors in order to avoid "motor loading" and to provide efficient movement of the structure using low torque, low cost servo-motors.

- 5 It should be understood that various modifications can be made to the preferred and alternative embodiments described and illustrated herein, without departing from the present invention, the scope of which is defined in the appended claims.

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CLAIM:

1. An image tracking system for use with an image capture device which obtains digitized image frames of an object, the image tracking system comprising:
- 5 (a) a support for holding the image capture device;
- (b) a processing device for determining an object location value for the object based on the digitized image frames generated by the image capture device;
- 10 (c) a position control device coupled to the support for, in use, rotating the support and the image capture device mounted therein about two axes based on the object location such that the object remains within a center region of each of the digitized image frames, said position control device comprising:
- 15 (i) a base;
- (ii) a first motor mounted on the base for generating a first rotational movement based on the object location and a first rotatable member mounted to the base for rotation about a first axis, said first rotatable member being connected to the first motor; and
- 20 (iii) a second motor mounted on the base for generating a second rotational movement based on the object location and a second rotatable member comprising the support mounted to the first rotatable member for rotation about a second axis and being connected to the second motor.
- 25 2. The image tracking system of claim 1, wherein the first motor comprises a first shaft member having a first shaft rotation axis longitudinally concentric with the first shaft member, and the second motor comprises a second shaft member having a second shaft rotation axis longitudinally concentric with the second shaft member,
- 30 such that the first shaft rotation axis and the second shaft rotation axis

are motionless and fixed relative to one another.

3. The image tracking system of claim 2, further comprising a first tendon for coupling the first motor to the first rotatable member and a second tendon for coupling the second motor to the second rotatable member.
4. The image tracking system of claim 3, wherein said second axis rotates about the first rotation axis during the rotation of the first rotatable member and said second tendon is substantially aligned with the first rotation axis so that rotation of the first rotatable member about the first rotation axis occurs without any relative rotation between the first and second rotatable members.
5. The image tracking system of claim 1, wherein the first axis and the second axis are orthogonal to each other.
6. The image tracking system of claim 1, wherein said base is adapted to rest on a support surface and has a cavity region formed therein for housing first and second stationary motors.
7. The image tracking system of claim 1, further comprising a mounting member for securing the first motor and the second motor, wherein the mounting member attaches to the base member.
8. The image tracking system of claim 7, wherein said mounting member further comprises a first vertical shaft member for engaging the first rotatable member.
9. The image tracking system of claim 8, wherein the first rotatable member further comprises a cylindrical hollow cavity for rotatably receiving the first vertical shaft member of the mounting member.

10. The image tracking system of claim 1, wherein the first rotational movement is a pan movement and the second rotational movement is a tilt movement.
- 5 11. The image tracking system of claim 1, wherein the first axis is stationary.
12. The image tracking system of claim 1, wherein the first axis is a major rotation axis and the second axis is a minor rotation axis rotatable about the first axis.
- 10 13. The image tracking system of claim 1, wherein the object has a selected color and the object location is the centroid of a region of the selected color within the digitized image frame.
14. The image tracking system of claim 1, wherein the image capture device is a video camera.
- 15 15. The image tracking system of claim 1, wherein the processing device is a microcontroller.
16. An image tracking system for use with first and second image capture devices which obtains digitized image frames of an object, the image tracking system comprising:
- 20 (a) a first support for holding the first image capture device and a second support for holding the second image capture device;
- (b) a processing device for determining an object location value for the object based on the digitized image frames generated by the image capture device;
- 25 (c) a position control device coupled to the support for, in use, rotating the first and second supports and the first and second

image capture devices mounted therein about four axes based on the object location such that the object remains within a center region of each of the digitized image frames, said position control device comprising:

- 5 (i) a base;
- (ii) a first motor mounted on the base for generating a first rotational movement based on the object location and a first rotatable member mounted to the base for rotation about a first axis, said first rotatable member being connected to the first motor;
- 10 (iii) a second motor mounted on the base for generating a second rotational movement based on the object location and a second rotatable member mounted to the first rotatable member for rotation about a second axis and being connected to the second motor;
- 15 (iv) a third rotatable member comprising the first support and a fourth rotatable member comprising the second support, said third and fourth rotatable members being mounted on the second rotatable member, at least one of said third and fourth rotatable members being rotably mounted to said second rotatable member; and
- 20 (v) a third motor mounted on the base for providing relative rotation between said third and said fourth rotatable members.

25 17. The image tracking system of claim 16, wherein said third motor provides rotation to said third rotatable member and further comprising a fourth motor mounted on the base for providing rotation to said fourth rotatable member.

18. The image tracking system of claim 17, wherein said third motor generates a third rotational movement based on the object location

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and rotates the third rotatable member and the fourth motor generates a fourth rotational movement based on the object location and rotates the fourth rotatable member.

19. The image tracking system of claim 18, wherein the first motor comprises a first shaft member having a first shaft rotation axis longitudinally concentric with the first shaft member, the second motor comprises a second shaft member having a second shaft rotation axis longitudinally concentric with the second shaft member, the third motor further comprising a third shaft member having a third shaft rotation axis longitudinally concentric within the third shaft member and the fourth motor further comprises a fourth shaft member having a fourth shaft rotation axis longitudinally concentric within the fourth shaft member, such that the second shaft rotation axis, the third shaft rotation axis and the fourth shaft rotation axis are each motionless and fixed relative to one another.
20. The image tracking system of claim 19, wherein the first shaft rotation axis is also motionless and fixed relative to the second shaft rotation axis, the third shaft rotation axis and the fourth shaft rotation axis.
21. The image tracking system of claim 19 or 20, further comprising a first tendon for coupling the first motor to the first rotatable member, a second tendon for coupling the second motor to the second rotatable member, a third tendon for coupling the third motor to the third rotatable member and a fourth tendon for coupling the fourth motor to the fourth rotatable member.
22. The image tracking system of claim 21, wherein when said first shaft member is stationary, at least one point on said first tendon remains fixed relative to said first axis.

23. The image tracking system of claim 21 or 22, wherein when said second shaft member is stationary, at least one point on said second tendon remains fixed relative to said second axis.
24. The image tracking system of claim 21 or 22 or 23, wherein when said third shaft member is stationary, at least one point on said third tendon remains fixed relative to said third axis.
25. The image tracking system of claim 21 or 22 or 23 or 24, wherein when said fourth shaft member is stationary, at least one point on said fourth tendon remains fixed relative to said fourth axis.
26. The image tracking system of claim 16, wherein the first image capture device comprises a first video camera and the second image capture device comprises a second video camera.
27. A method of tracking an object, said method comprising the steps:
(a) obtaining a series of digitized image frames from the image capture device;
(b) identifying the object within each of the digitized frames; and
(c) providing a first rotational movement to the image capture device about a first axis using a first motor and providing a second rotational movement to the image capture device about a second axis using a second motor such that the object remains within a center region of each of the digitized frames.
28. The tracking method of claim 27, wherein step (b) further comprising the steps:
(i) determining object center location values for the object based on the digitized image frames;
(ii) determining frame center location values for the digitized image frames; and

- (iii) comparing the object center location values with the frame center location values to determine the amount of rotation necessary to maintain the object within a center region of each of the digitized frames.

5 29. The tracking method of claim 28, wherein the digitized image frames contain an object image for the object.

30. The tracking method of claim 29, wherein determining the object center location values for the object comprises calculating the centroid of the object image within each digitized image frame.

10 31. The tracking method of claim 30, wherein the object image is a region of a selected color.

15 32. The tracking method of claim 31, wherein the step of determining the object center location values for the object comprises locating a pixel located at the center of a group of pixels within said region of a selected color.

33. The tracking method of claim 31, wherein the step of determining frame center location values comprises calculating the centroid of the digitized image frame.

20 34. The tracking method of claim 31, wherein step (c) requires rotating the image capture device such that the object center location value and the frame center location value are substantially the same.

35. The tracking method of claim 27, wherein the image capture device is a video camera.

36. The tracking method of claim 27, wherein the image capture device is

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a first video camera and a second video camera.

5 37. The tracking method of claim 27, wherein the first stationary motor provides the image capture device with pan movement and the second stationary motor provides the image capture device with tilt movement.

38. The tracking method of claim 37, wherein the pan movement consists of rotation about a major rotation axis and the tilt movement consists of rotation about a minor rotation axis.

10 39. The tracking method of claim 27, wherein step (c) further comprises using first and second motors mounted on a common base to provide first and second rotational movements to the image capture device.

40. The tracking method of claim 35, wherein the minor rotation axis rotates about the major rotation axis.

15 41. The tracking method of claim 36, wherein the major rotation axis is stationary relative to said first shaft rotation axis.

20 42. The tracking method of claim 27, wherein step (c) further comprises providing a third rotational movement to the image capture device about a third axis using a third motor and providing a third rotational movement to the image capture device about a fourth axis using a fourth motor such that the object remains within a center region of each of the digitized frames.

25 43. The tracking method of claim 42, wherein the first rotational movement is a major pan movement, the second rotational movement is a tilt movement, the third rotational movement is a first

minor pan movement and the fourth rotational movement is a second minor pan movement.

- 5 44. The image tracking system of claim 42, wherein when said first shaft member is stationary, said first rotatable member remains fixed relative to said first axis
45. The image tracking system of claim 42 or 44, wherein when said second shaft member is stationary, said second rotatable member remains fixed relative to said second axis.
- 10 46. The image tracking system of claim 42, 44 or 45, wherein when said third shaft member is stationary, said third rotatable member remains fixed relative to said third axis.
47. The image tracking system of claim 42, 44, 45, or 46, wherein when said fourth shaft member is stationary, said fourth rotatable member remains fixed relative to said fourth axis.
- 15 48. A tension regulation device for controlling the amount of tension applied to a tendon, said tension regulation device comprising:
- (a) a platform;
 - (b) a resilient column rotatably mounted on the platform and having a cross-section with a first radius;
 - 20 (c) a splined column rotatably mounted on the platform and having a plurality of spline members extending radially and having a cross-section with a second outer radius, said splined column being adapted to receive a portion of the tendon therearound;
 - 25 (d) said resilient column being spaced apart from said splined column and rotatably mounted on said platform at a distance equal to slightly less than the sum of the first and second radius; and

5 (e) such that in the absence of tension the spline members slightly deform said resilient column to restrict rotational movement of said spline column and said tendon and in the presence of tension, the spline members are forced to travel along the surface of said resilient column and to unwind the portion of the tendon around the splined column.

10 49. The tension regulation device of claim 48, wherein said platform is mounted within a neck tendon support structure, said neck structure having two orifices, each orifice adapted to receive a portion of the tendon.

50. The tension regulation device of claim 48, wherein said platform is mounted on a vertical shaft, said vertical shaft having a surface being adapted to receive a portion of the tendon.

15 51. The tension regulation device of claim 48, wherein the axis of rotation of said resilient column is orthogonal to said platform.

52. The tension regulation device of claim 48, wherein the axis of rotation of said splined column is orthogonal to said platform.

20 53. A tendon motor pulley for coupling a tendon length to a motor shaft, said tendon motor pulley comprising:

- 25 (a) a first disc;
- (b) an second disc, the first and second discs having facing surfaces;
- (c) a hub positioned concentrically between said first and second discs; and
- (d) at least one engagement means extending between the first and second discs and located radially outwardly from the hub, whereby a tendon can travel freely around the hub and the

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54. The tendon motor pulley of claim 53, wherein said engagement means is a plurality of protrusions and a plurality of recesses, said recesses adapted to receive said protrusions in a snap fit arrangement.
55. The tendon motor pulley of claim 53, wherein said hub is disc-shaped.

ABSTRACT OF THE DISCLOSURE

An image tracking system for generating digitized image frames of a moving object using an image capture device and a position control device. The image capture device and determining a location value for an object image within each of the digitized image frames. The position control device is coupled to the image capture device to receive the location value of the object image and generates a plurality of control signals which are sent to the position manipulating device. The position control device also uses the plurality of control signals and generates a plurality of rotational movements which position the image capture device, such that the location value of the object image remains within a center region of each of the digitized image frames and such that rotation along different rotation axis occurs independently.

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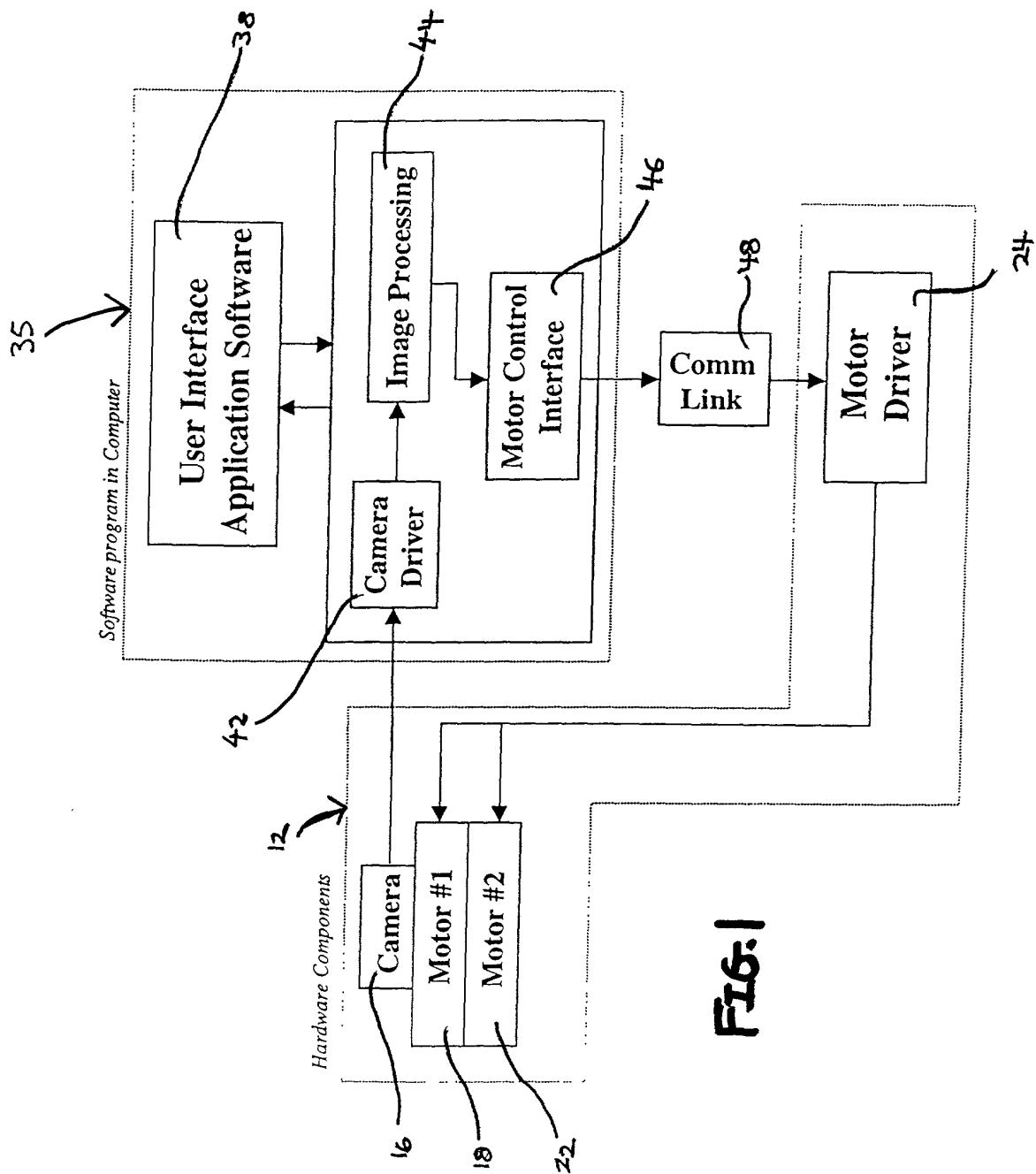


FIG. 1

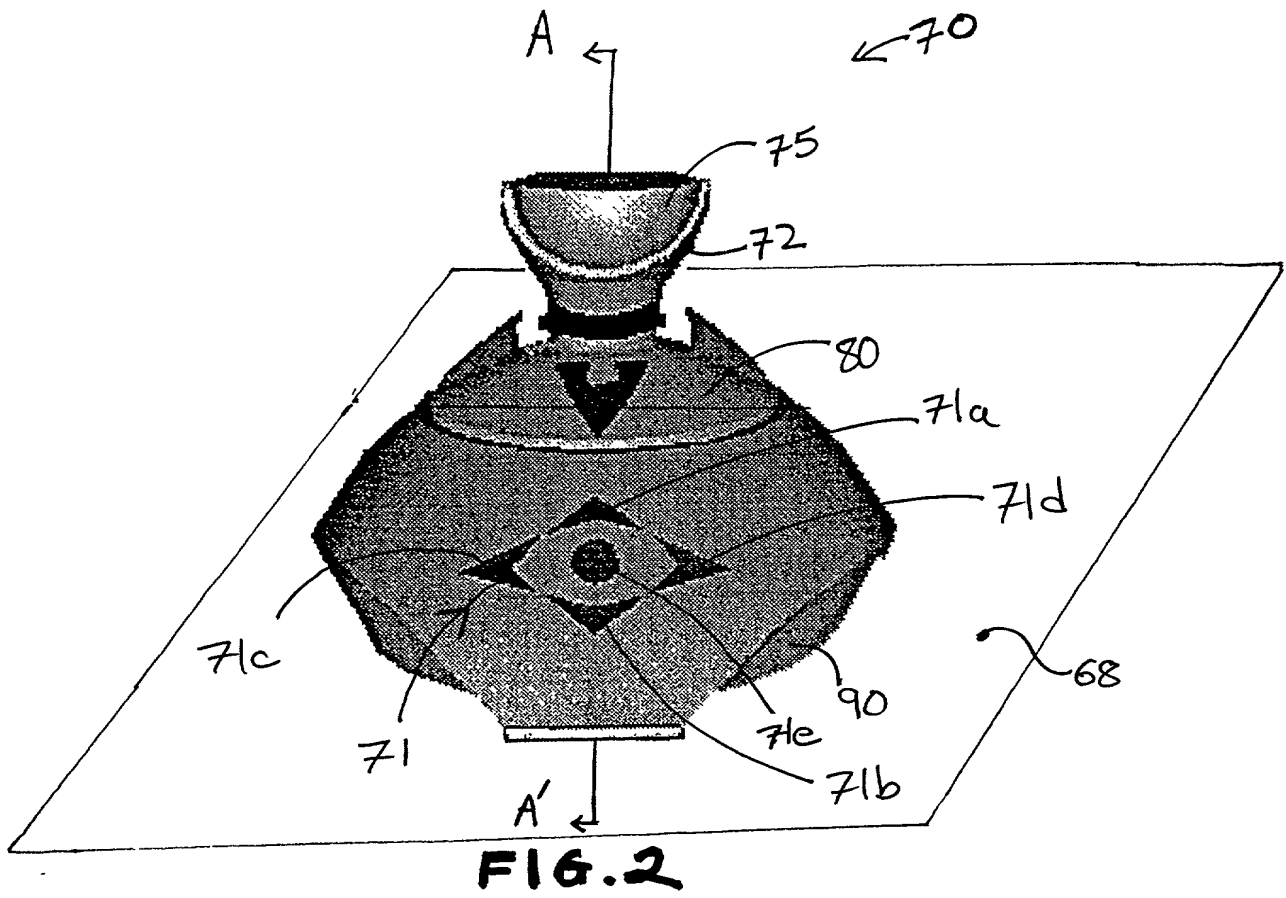
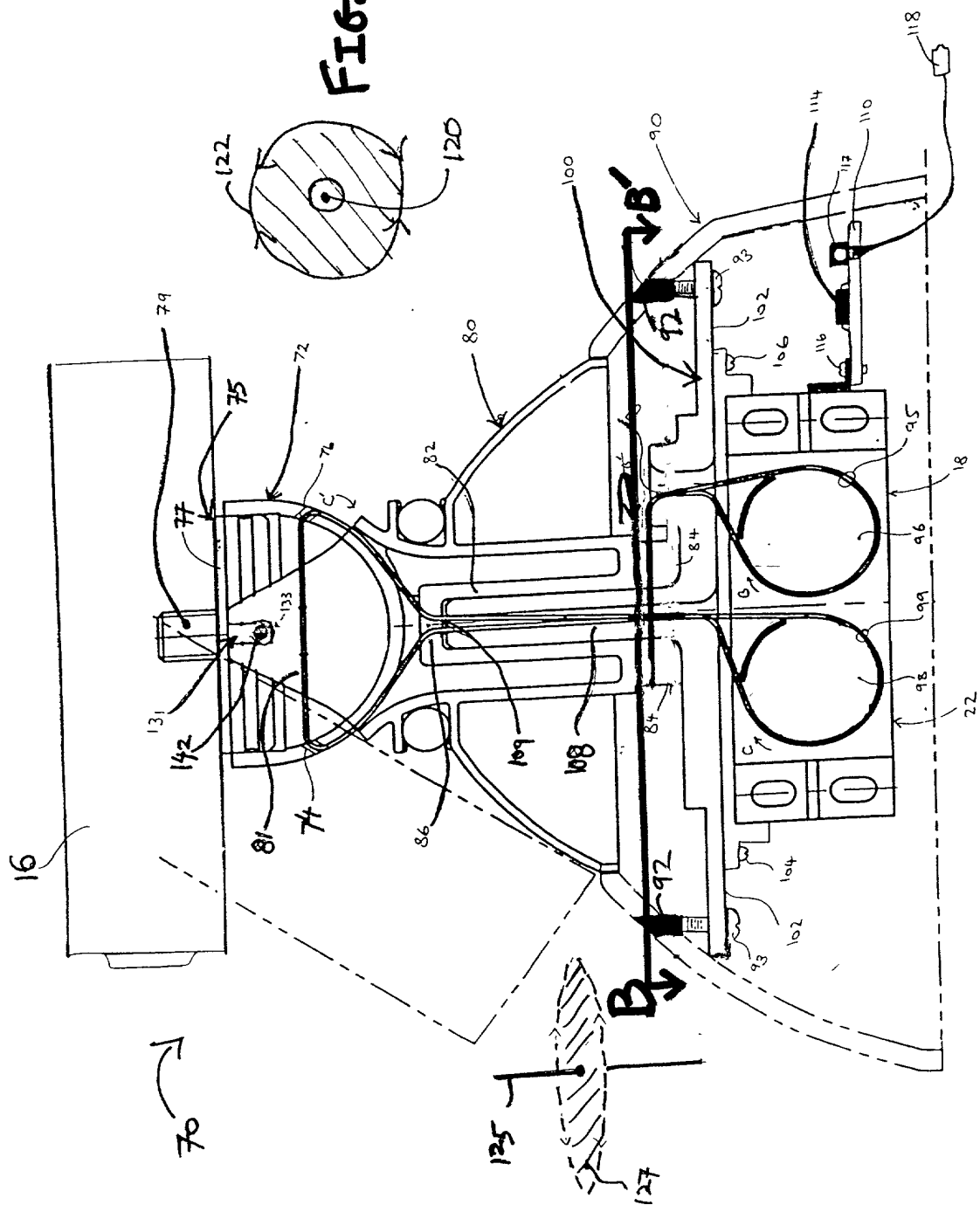


Fig. 3A



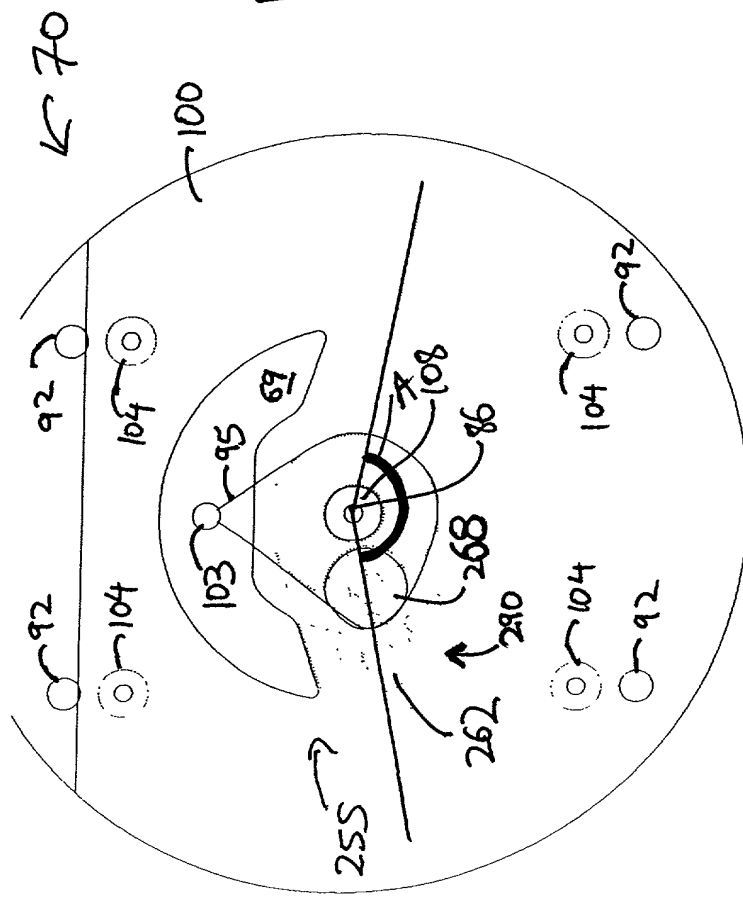


FIG. 3B

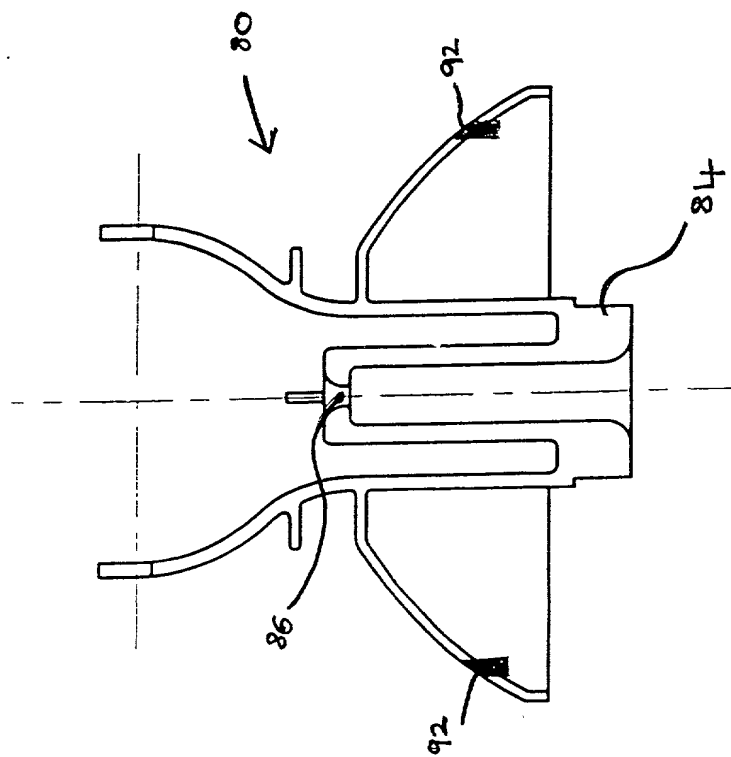


FIG. 4A

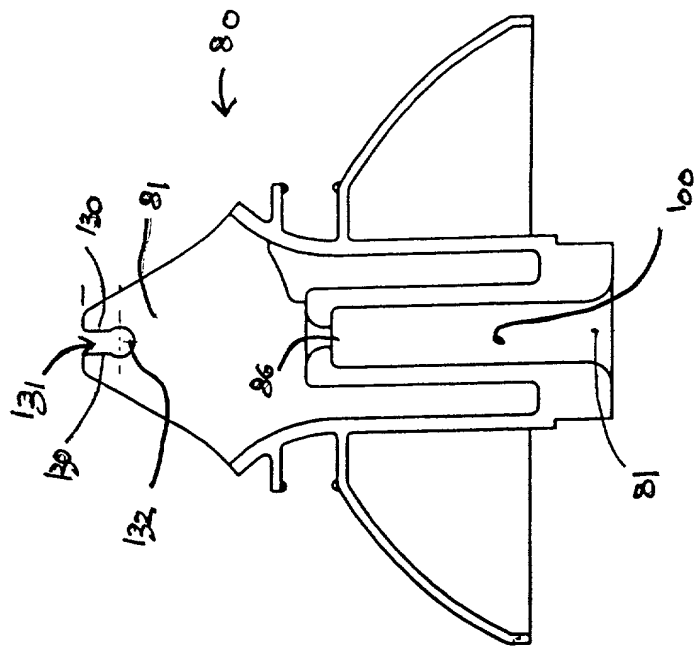


FIG. 4B

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FIG. 5A

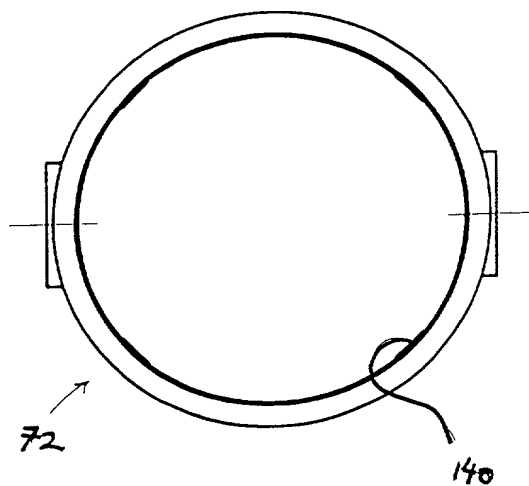
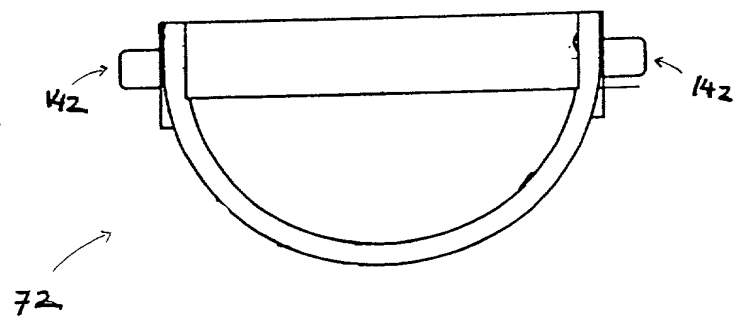


FIG. 5B



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FIG. 6A

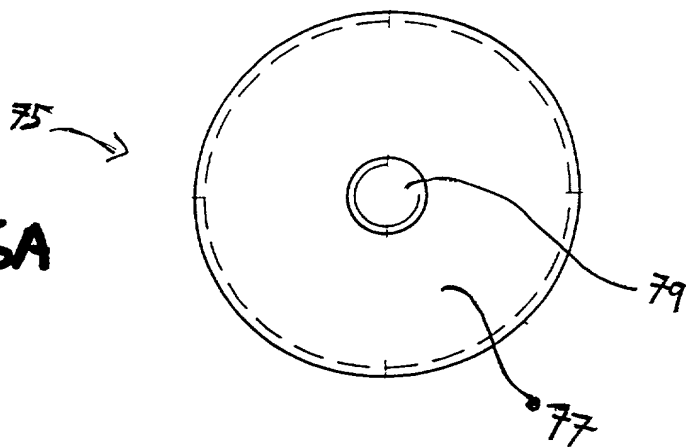
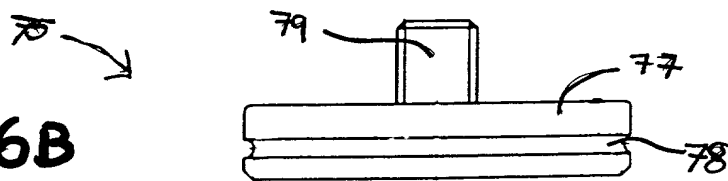


FIG. 6B



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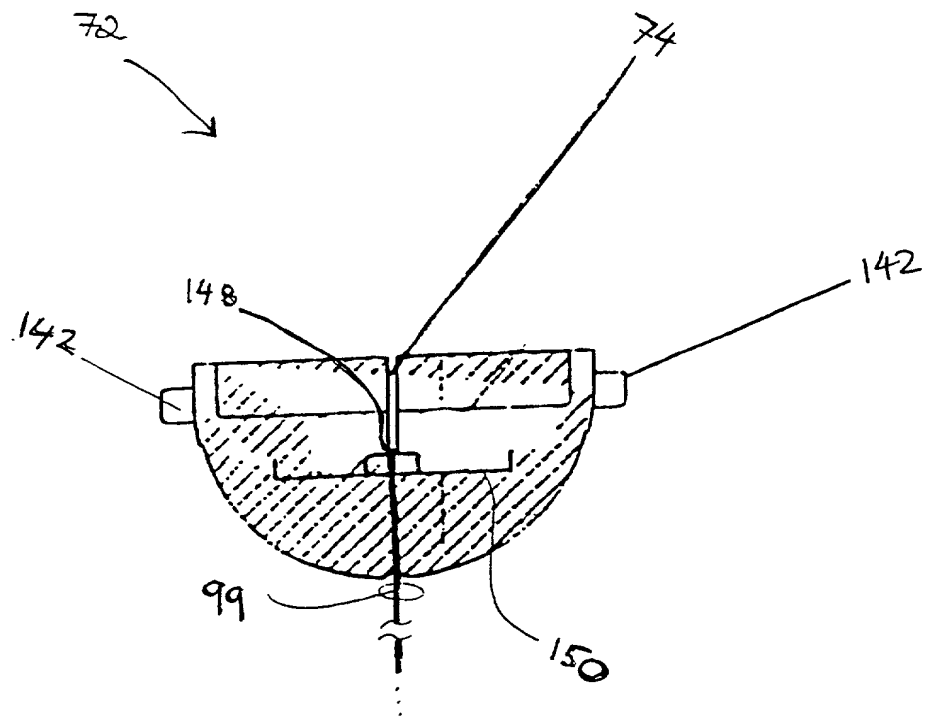
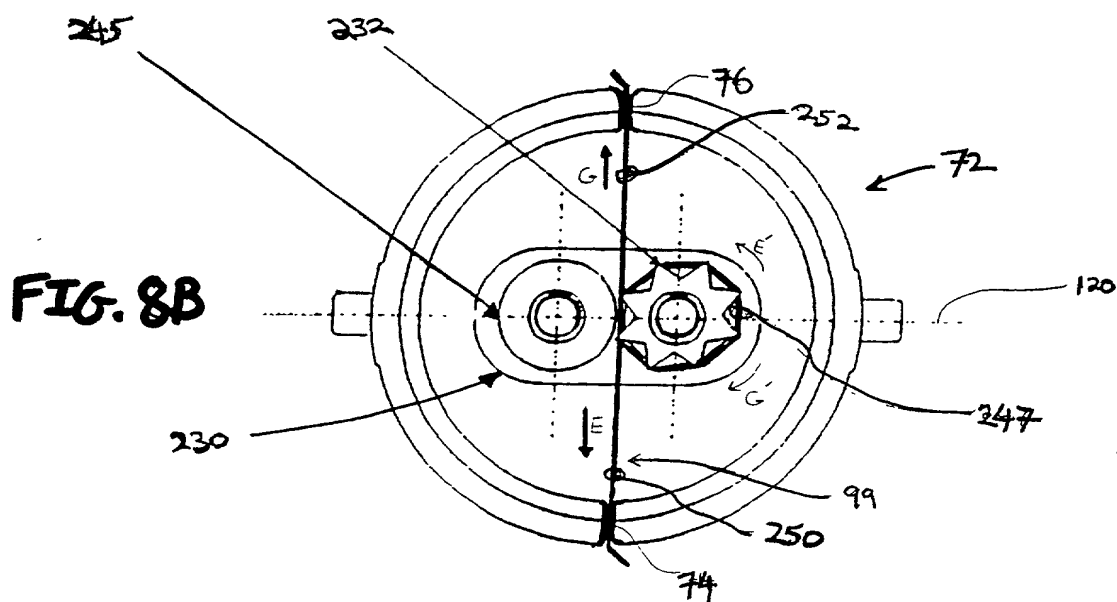
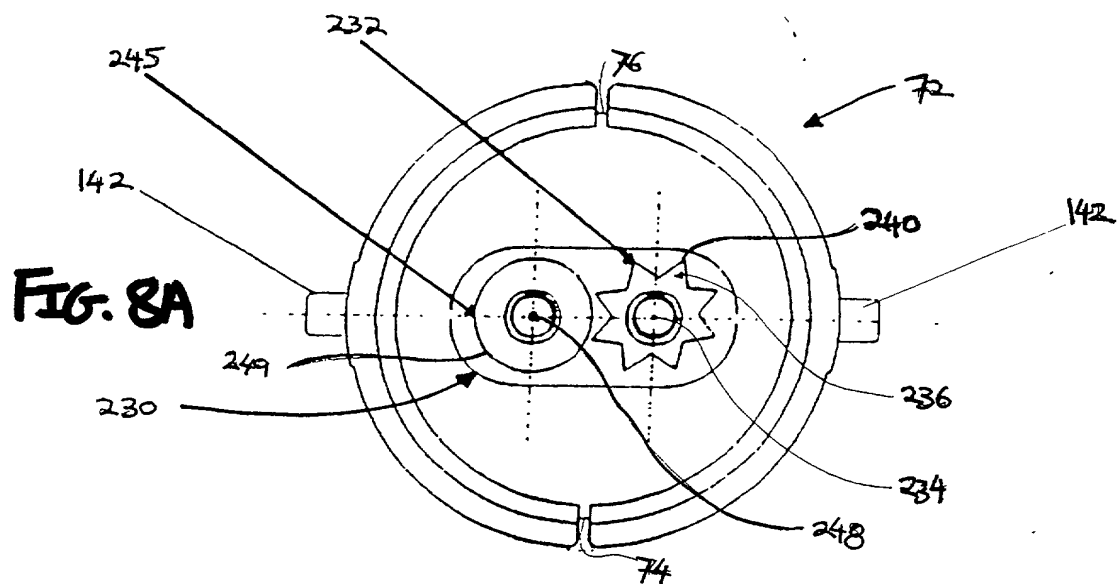


FIG. 7

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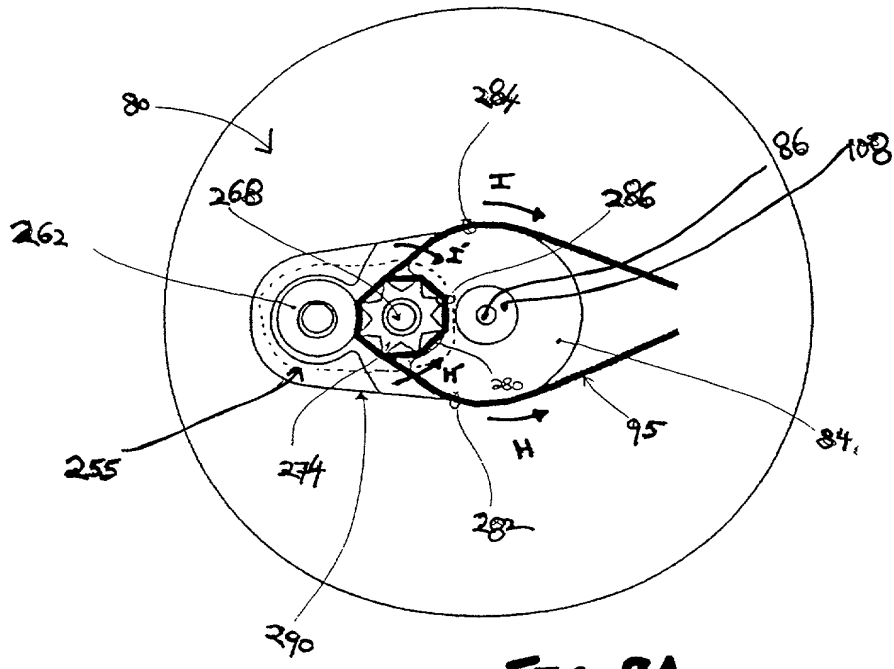


FIG. 9A

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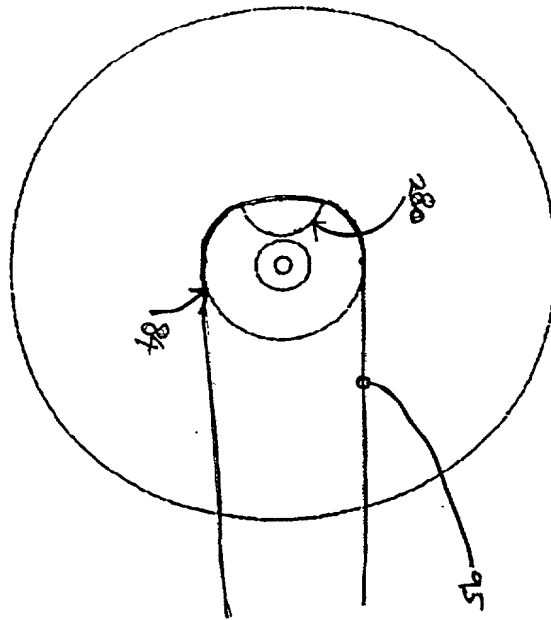
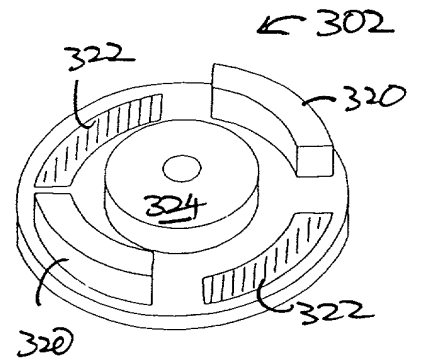
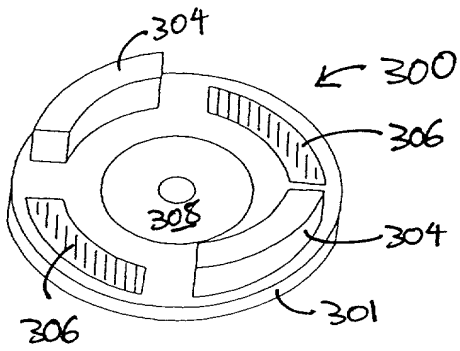
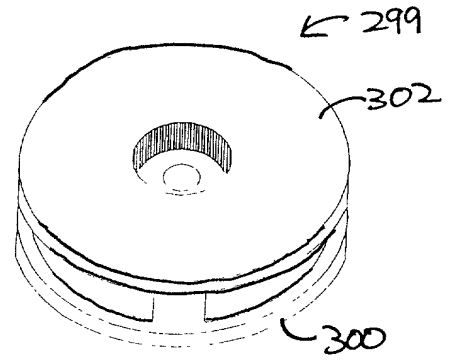
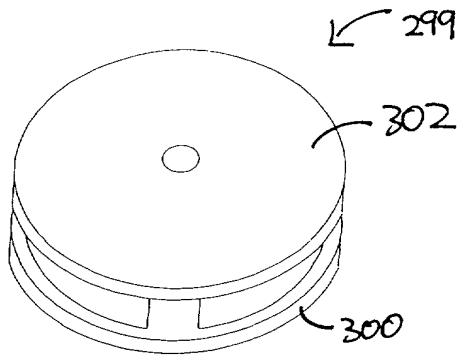


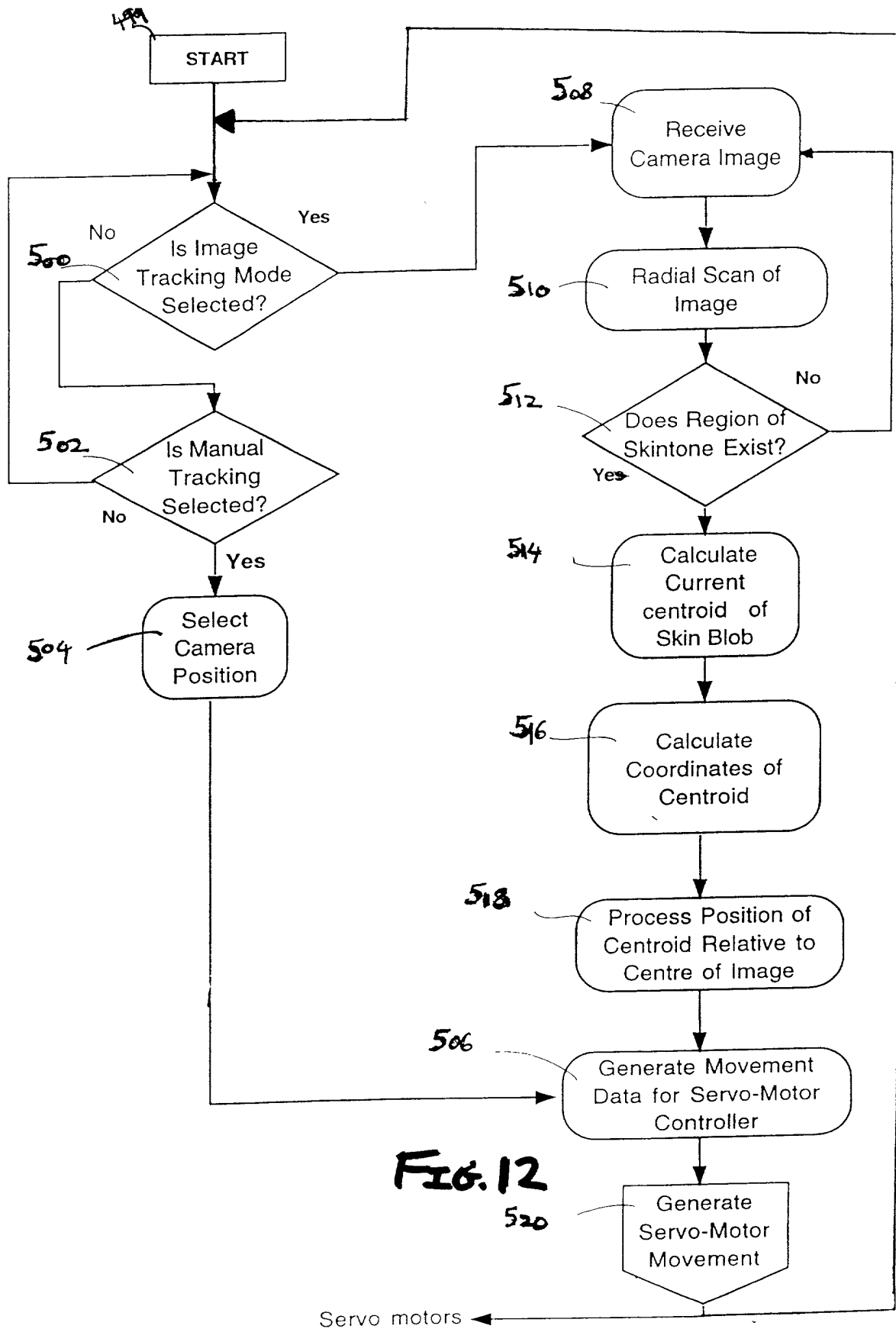
FIG. 9B

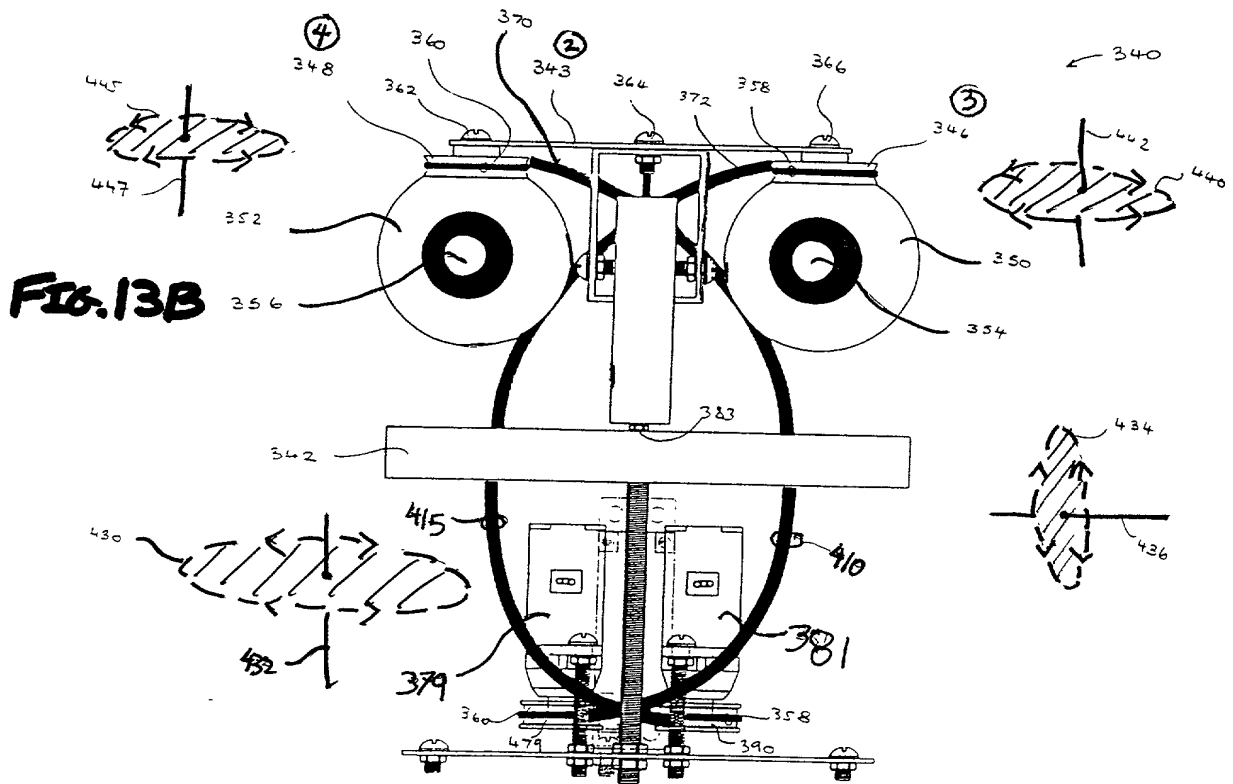
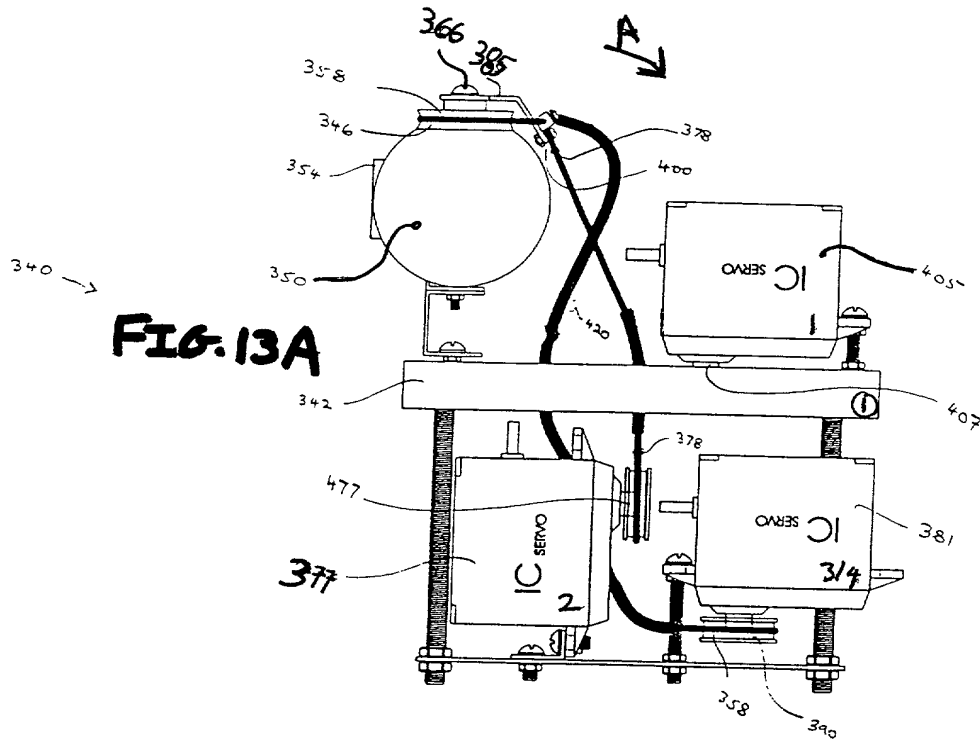


A diagram of a circular device, labeled 300, which has a central circular hole. A dashed line indicates an outer ring or boundary. A line, labeled 310, points to the central hole.

FIG. 3 is a top-down view of a circular device 300. The device has a central circular opening 312. The device is defined by a dashed circular outline and a solid circular outline. The central opening 312 is a small circle in the center of the device.

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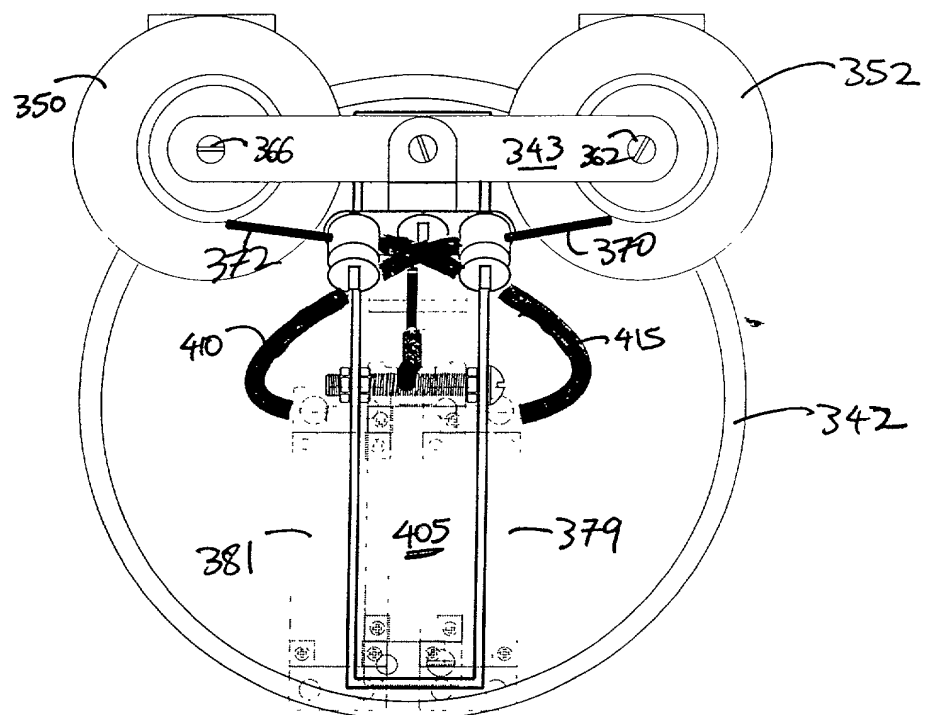



FIG. 13B

The Basic Controls

Use, Page 1 of y

This is a picture of the **Control Panel**, which you see when you start the TrackerCam software.

To learn more about a part of the **Control Panel**, click on it in the picture.

These are just TrackerCam's basic controls. You can make a set of additional controls, called the **Tool Panel** appear when you click the button on the bottom-left of the basic control panel that looks like this; 

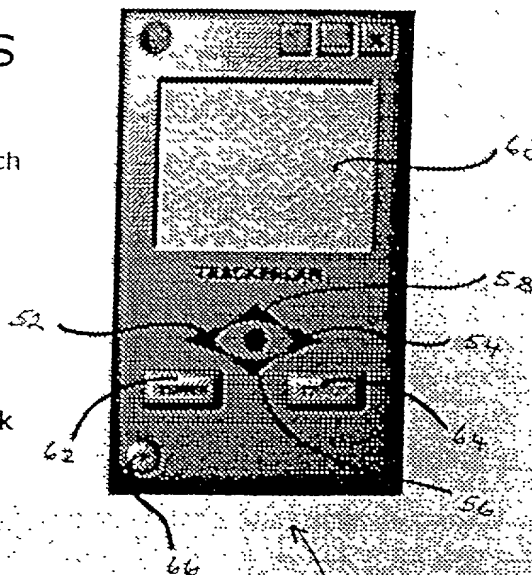


FIG 14

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DESIGN
PATENT APPLICATION
(37 CFR 1.63)**☒ Declaration Submitted with Initial Filing
OR
☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number 11309-001

First Named Inventor Gilbert Verghese

COMPLETE IF KNOWN

Application Number N/A

Filing Date N/A

Group Art Unit N/A

Examiner Name N/A

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

IMAGE TRACKING SYSTEM AND METHOD

the specification of which

(Title of the Invention)

☒ is attached hereto
OR☐ was filed on (MM/DD/YYYY) as United States Application Number or PCT International
Application Number and was amended on (MM/DD/YYYY) (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?	
				YES	NO
			<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>

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Application Number(s)	Filing Date (MM/DD/YYYY)	<input type="checkbox"/> Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

[Page 1 of 2]

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U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)

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H. Roger Hart	26,426	Robert B. Storey	33,108
David W.R. Langton	27,747	John R. Rudolph	38,003
C. Lloyd Sarginson	29,245	Robin L.A. Coster	38,016
Timothy J. Sinnott	31,083	Michael E. Charles	38,036

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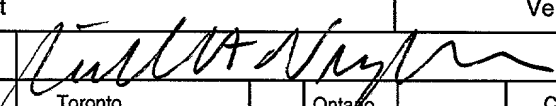
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City	Toronto	State	Ontario	ZIP	M5H 3Y2
Country	Canada	Telephone	(416) 364-7311	Fax	(416) 361-1398

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Name of Sole or First Inventor:

☐ A petition has been filed for this unsigned inventor

Given Name (first and middle (if any))				Family Name or Surname			
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Inventor's Signature						Date	Oct 19, 2000
Residence: City	Toronto	State	Ontario	Country	CANADA	Citizenship	Canadian
Post Office Address	6 Hoskin Avenue, Suite 350						
Post Office Address							
City	Toronto	State	Ontario	ZIP	M5S 1H8	Country	CANADA

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